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TONGUE RIVER DAM

MANUAL FOR
OPERATION AND MAINTENANCE

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TONGUE RIVER DAM

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PROJECT DESCRIPTION

OVERVIEW

The Tongue River Dam and Reservoir are located in the southeast panhandle of Big Horn County northeast of Decker, Montana (see Figures 1, 2 and 3). The upper end of the reservoir is approximately 5 miles north of the Montana-Wyoming state line. The dam itself is approximately 15 miles north of the state line, just south of the Big Horn-Rosebud county line.

The dam is owned by the Montana Department of Natural Resources and Conservation (DNRC) and is managed by the State Water Projects Bureau (SWPB) of the DNRC. The Tongue River Water Users Association (herein called the "association") operates and maintains the dam.

DNRC owns the land upon which the dam is situated. DNRC either owns the land or owns flood easements for the land inundated by the reservoir. In addition, DNRC owns or controls the land underlying the access road from Highway 314 to the dam.

Construction of the Tongue River Dam was completed in 1940 by the Montana State Water Conservation Board. In 1978, a flood discharging less than 10% of the rated spillway capacity did approximately $1,000,000 damage to the spillway. Between that flood and 1999, the reservoir was operated conservatively to reduce use of the spillway.

From 1996 to 1999, DNRC undertook a major rehabilitation of the 60-year old dam to bring it into compliance with current dam safety standards. The rehabilitation included raising the reservoir full-pool level by four feet. A new primary and an emergency spillway were constructed. A new outlet tunnel and gate system was constructed, and the existing outlet works were rehabilitated to act as an auxiliary outlet system.

Water from the reservoir is used primarily to irrigate lands downstream all the way to the confluence of the Tongue and Yellowstone Rivers at Miles City, Montana. In addition to water contracts for irrigation, the reservoir holds a minor amount of industrial water (coal mines) and supplies some water to the fish hatchery at Miles City. The new water stored as a result of the rehabilitation is used to supply a portion of the Northern Cheyenne Tribe's federally reserved water right. Even though the reservoir is relatively small compared to the size of the drainage basin, some flood control benefits do accrue to the project. Over the past several decades, fishing and flat-water recreation at the reservoir have become increasingly important.

EMBANKMENT

The earthfill dam is 93 feet high and approximately 1,824 feet long with a 35.5 feet wide crest. The reservoir has an active storage of 79,071 acre-feet (af) at the spillway crest.

OUTLET WORKS

The dam has two low-level outlet conduits -- a primary and an auxiliary outlet works. Both outlet works are located in the left abutment. The gates are hydraulically operated from control panels located at the top of each tower in the gatehouse. The hydraulic system can be operated manually if necessary. The maximum combined capacity of the two outlet works is 3,245 cfs at normal full pool (elevation 3,428.4 feet). The actual low-level outlet capacity is approximately 10% greater than the calculated capacity.

There are bulkhead gates for each of the low-level outlet conduits for closing off the portion of the outlet conduits upstream from the gates. The bulkhead gates can be installed into gate slots in the downstream side of the intake towers by a crane. The bulkhead gates are stored on site.

Primary Outlet Works: The primary low-level outlet conduit was tunneled through the left abutment as part of the dam rehabilitation project and is located about 200 feet to the left of the auxiliary low-level outlet conduit. The primary outlet has a calculated capacity of 1,642 cfs with the reservoir at the spillway crest elevation of 3,428.4 feet.

The primary outlet consists of a rectangular reinforced concrete drop inlet structure, then a nine-foot diameter circular reinforced concrete conduit approximately 278 feet long, the gate chamber with a 4.5-foot by 7.5-foot fixed-wheel emergency gate and a 4.5-foot by 7.5-foot bonneted slide operating gate, then a nine-foot diameter straight legged horseshoe shaped conduit approximately 389 feet long, followed by a flipbucket energy dissipater and then a rock lined stilling basin. The intake structure has trash racks on three sides and the top. There is a gate slot at the transition from the intake tower to the conduit for the installation of a nine-foot square bulkhead gate. There is also a fill pipe located just downstream from the bulkhead gate slot for filling the upstream portion of the tunnel after it has been dewatered.

The emergency gate tower is a wet tower when the fixed-wheel gate is in the open position. The fixed-wheel gate is an upstream sealing gate, such that when the gate is in the closed position, the tower is dry. **The fixed-wheel gate is intended to be operated in either the fully open or fully closed position and not used to throttle flows.**

The operating gate tower is a dry tower. The operating gate is a bonneted slide gate located in the bottom of the tower. There is a drainpipe located in the bottom of the tower so that any seepage that should enter the tower will be drained into the downstream portion of the low-level outlet conduit.

The air vent for the gates consists of three two-foot diameter pipes, which enter the low-level outlet conduit just downstream from the gate chamber.

Auxiliary Outlet Works: The auxiliary low-level outlet was the original low-level outlet conduit and was also tunneled through the left abutment. The auxiliary outlet has a calculated capacity of 1,603 cfs with the reservoir at the spillway crest elevation of 3,428.4 feet.

The auxiliary low-level outlet consists of a rectangular reinforced concrete drop inlet structure, then a sixteen-foot diameter modified horseshoe shaped reinforced concrete conduit approximately 245 feet long, the gate chamber with a 4.5-foot by 7.0-foot fixed-wheel emergency gate and a 4.5-foot by 7.0-foot cast iron sluce operating gate, then a sixteen-foot diameter modified horseshoe shaped conduit approximately 520 feet long, followed by a flipbucket energy dissipater and then a rock lined stilling basin. The intake structure has trash racks on three sides and the top. There is a gate slot in the intake tower for the installation of two 10-foot wide by 37-foot high bulkhead gates. There is a 2-foot square sluce gate located in one of the bulkhead gates for filling the upstream portion of the tunnel after it has been dewatered.

The emergency gate tower is a wet tower when the fixed-wheel gate is in the open position. The fixed-wheel gate is an upstream sealing gate, such that when the gate is in the closed position, the tower is dry. **The fixed-wheel gate is intended to be**

operated in either the fully open or fully closed position and not used to throttle flows.

The operating gate tower is a wet tower. The operating gate is a cast iron sluce gate, with the hoist located at the top of the tower. The sluce gate has a tendency to vibrate when in operation at different openings at different heads. **The gate should be operated so that the gate does not vibrate.**

The air vent for the gates consists of a three-foot diameter pipe, which enters the low-level outlet conduit just downstream from the gate chamber.

SPILLWAYS

The dam has a principal and an emergency spillway. Rating curves and tables for the two spillways are included in Appendix B.

Principal Spillway: The principal spillway is a four-cycle labyrinth weir with an effective crest length of 668 feet inside of a 150-foot wide chute that tapers to 100 feet wide ending in a flipbucket. The spillway crest is at elevation 3,428.4 feet. The primary spillway has a design capacity of 38,800 cfs at elevation 3,440.0 feet and 50,000 cfs at the dam crest elevation of 3,444.0 feet.

Emergency Spillway: The emergency spillway is an uncontrolled chute located over the center of the dam. It consists of a 650-foot wide straight chute with an ogee crest, a stepped chute and finally a stilling basin. It is constructed of roller compacted concrete (RCC) with precast concrete facing panels and conventional reinforced concrete on top of each step. The crest is at elevation 3,431.5 feet. The energy from the flowing water is dissipated by the cascading effects of the concrete steps, and any remaining energy is dissipated in the RCC stilling basin at the toe of the dam. The spillway is designed to begin flowing at flows greater than the 100-year flood event. The spillway has a design capacity of 61,200 cfs at elevation 3,440.0 feet and 109,200 cfs at the dam crest elevation of 3,444.0 feet.

DRAINS

There are a number of drains that have been installed in and around the dam.

Original Toe Drain: The original toe drain is located along the toe of the dam and originally exited into the old river channel. The drain has been rerouted to the right flume (9" Parshall) in the flume vault building and then discharges into the original river channel.

Principal Spillway Drains: The principal spillway has four drains. There is a 12-inch perforated drain along the outside wall on each side of the spillway. The right 12-inch drain exits through the end wall into the tailrace channel. The left 12-inch drain exits on the slope above the outlet access area, and then flows above ground to a catch basin near the primary outlet portal.

A 15-inch perforated drain is along the downstream toe of the clinker in the left abutment. This drain flows through a measuring flume (12" Palmer-Bowlus) in the outlet access area, and then discharges into the auxiliary outlet flipbucket. Normally this drain is dry.

There is also a 6-inch drain located under the flip bucket of the spillway to drain a coal seam. This drain exits through the end wall into the tailrace channel at elevation 3,350 feet. The drain outlet is normally submerged.

Emergency Spillway Drains: The emergency spillway has two drains. One drain is a 15-inch lateral grid type drain under the stilling basin which exits to the left flume (9" Parshal) in the flume vault building, and then discharges into the original river channel. There is a manhole and a cleanout on each side of the spillway for servicing and inspecting the drain.

The second drain (12 inch) is under the lower portion of the emergency spillway and exits into the middle flume (12" Palmer-Bowlus) in the flume vault building, and then discharges into the original river channel. This drain acts as a safety backup to the 15-inch drain, and is typically dry. There have been no recorded flows since construction in 1998. There is a manhole on each side of the spillway for servicing and inspecting the drain.

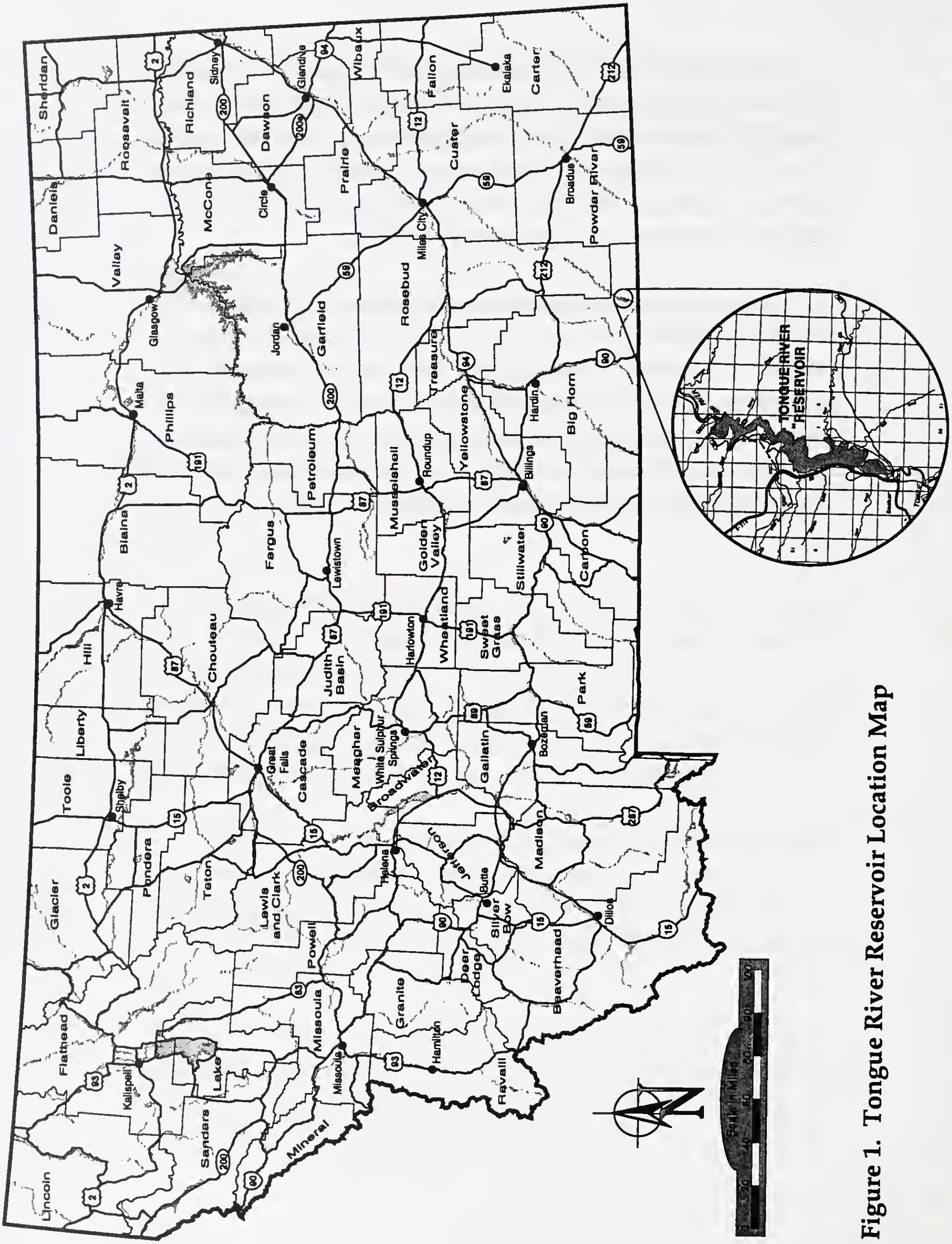


Figure 1. Tongue River Reservoir Location Map

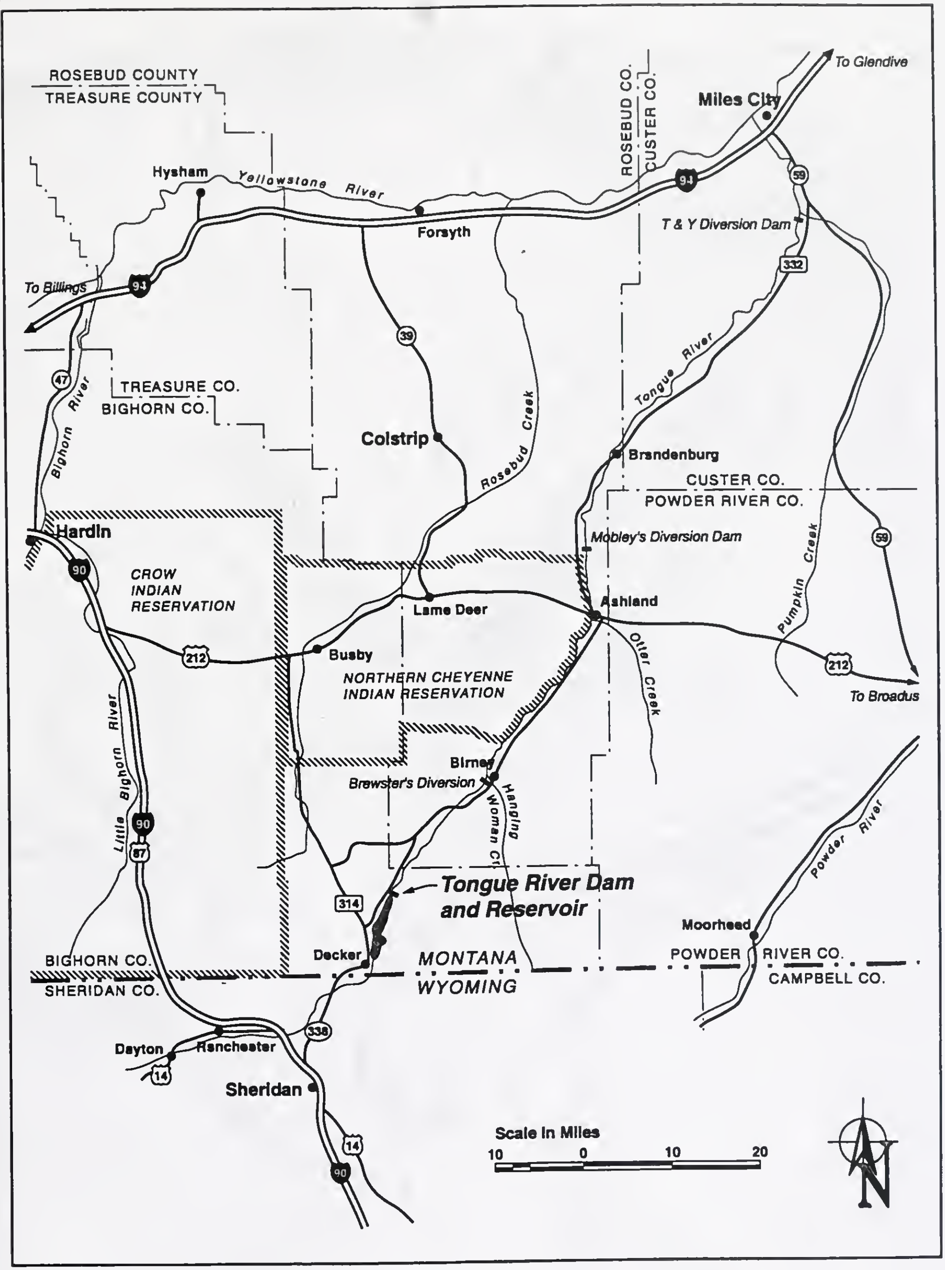


Figure 2. Tongue River Reservoir Vicinity Map

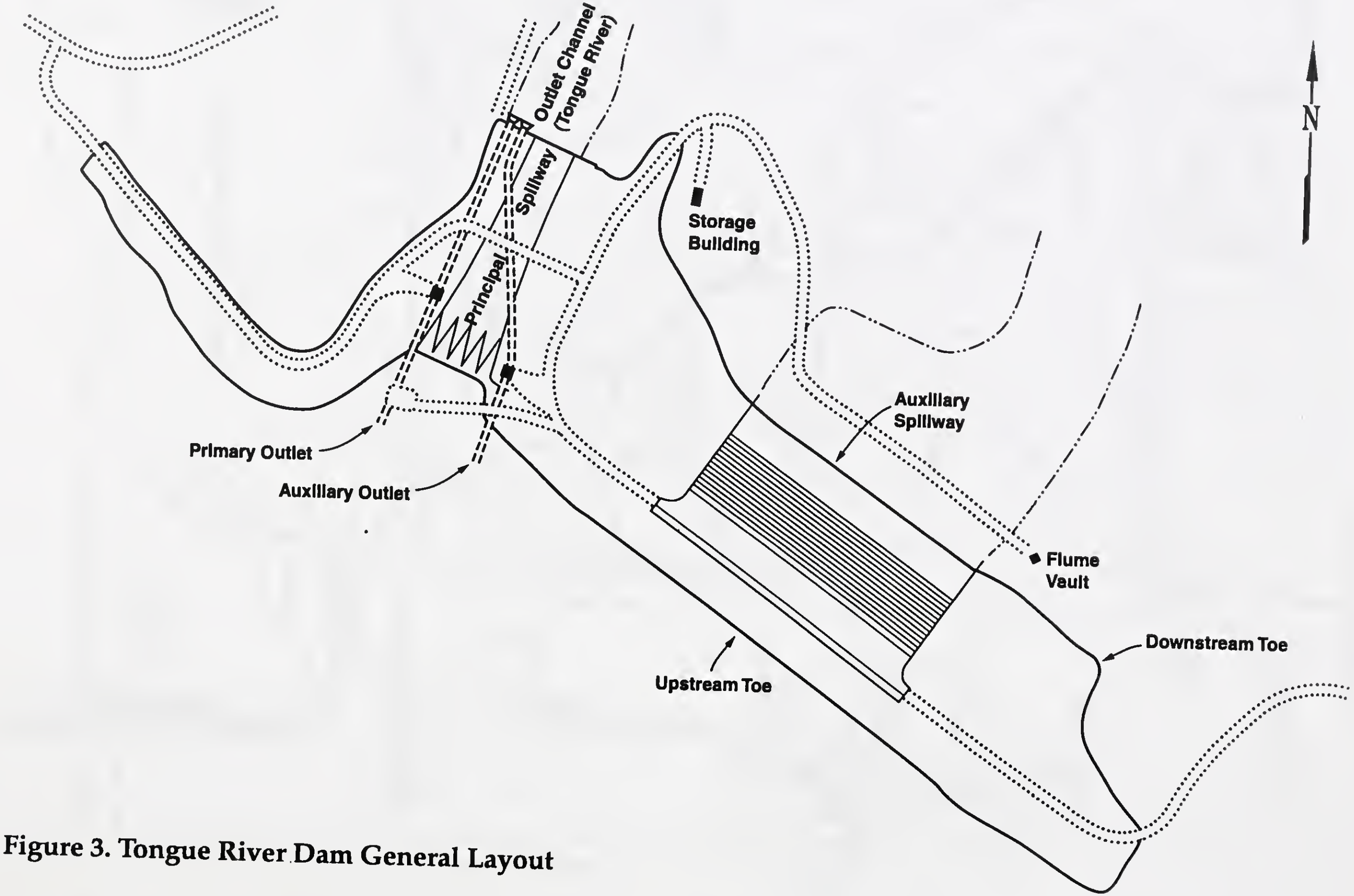
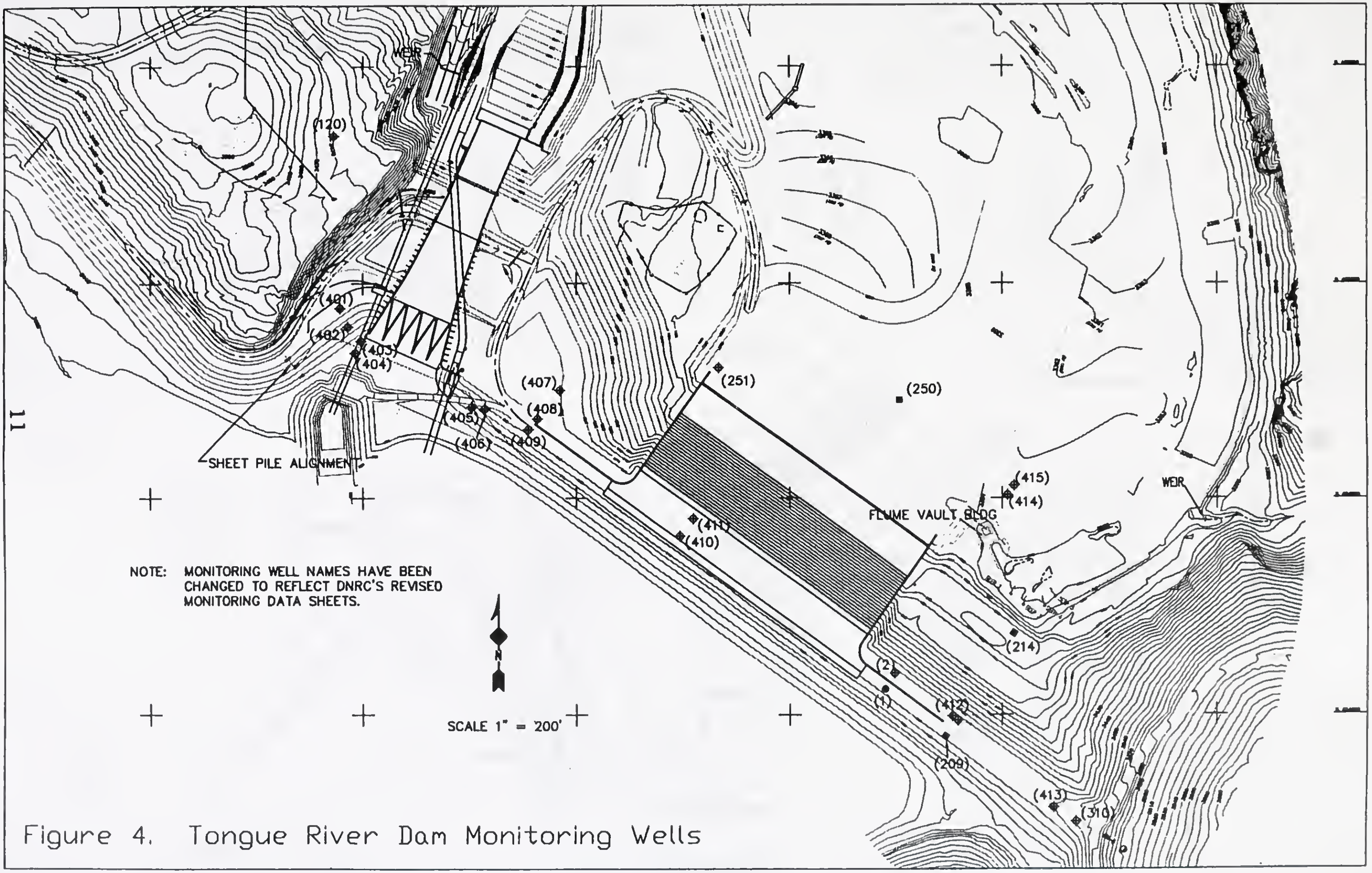
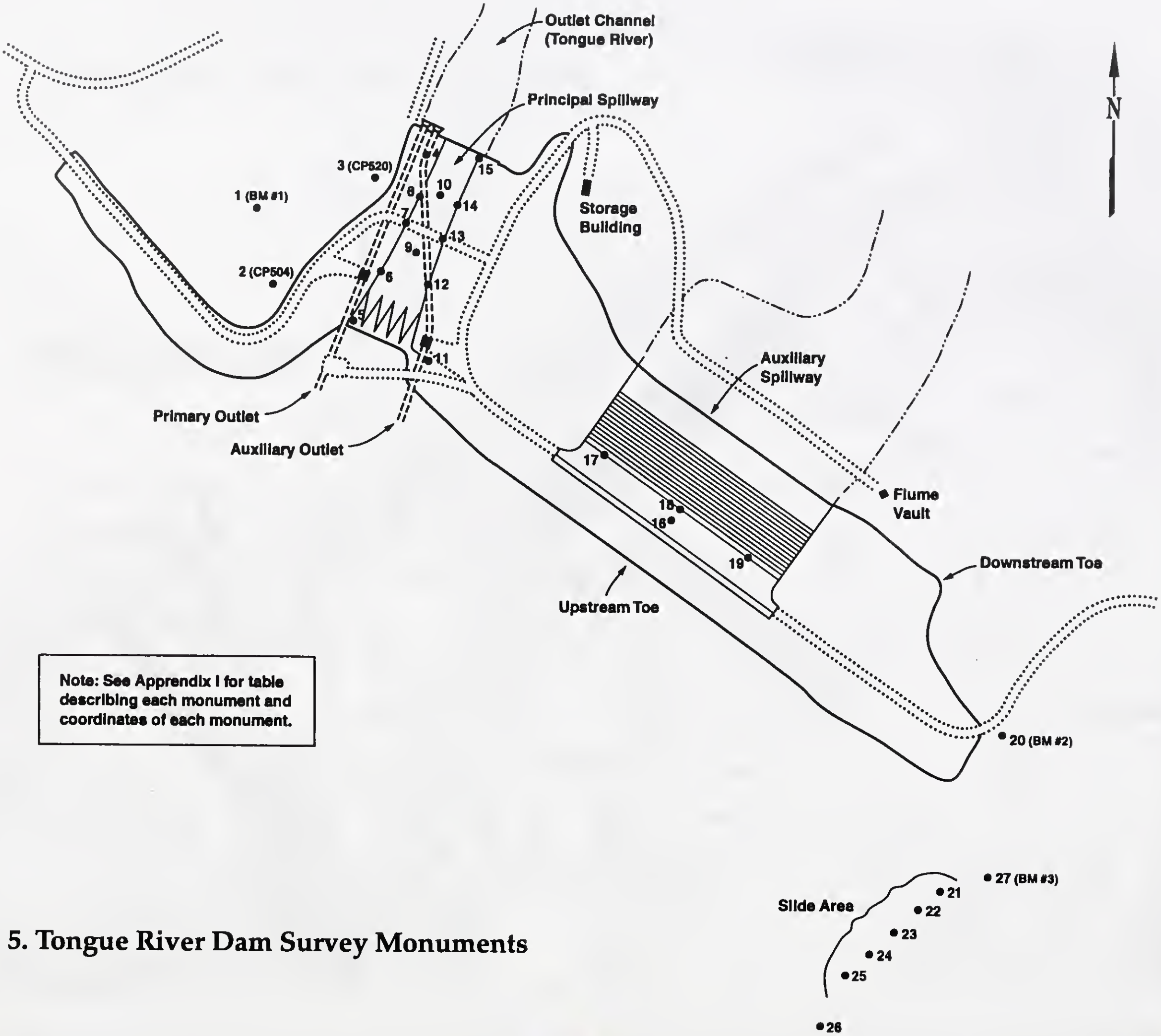


Figure 3. Tongue River Dam General Layout



NOTE: MONITORING WELL NAMES HAVE BEEN CHANGED TO REFLECT DNRC'S REVISED MONITORING DATA SHEETS.

Figure 4. Tongue River Dam Monitoring Wells



Note: See Apprendix I for table describing each monument and coordinates of each monument.

Figure 5. Tongue River Dam Survey Monuments

STATISTICAL INFORMATION

1. General

a. Owner	Montana Department of Natural Resources and Conservation (DNRC)
b. Operator	Tongue River Water Users Association
c. Location	Section 13 Township 8 South Range 40 East and Section 18 Township 8 South Range 41 East
d. Latitude	45° 07’ 48”
Longitude	106° 46’ 06”
e. County – State	Big Horn – Montana
f. Watershed Location	Tongue River, Yellowstone River Basin
g. Drainage Area	1,760 square miles

2. Principal Elevation (feet above sea level)

a. Maximum Dam crest	3,444.0 feet
b. Settled Dam Crest	3,444.0 feet
c. Auxillary Spillway Crest	3,431.5 feet
d. Principal Spillway Crest	3,428.4 feet
e. Normal Full Pool	3,428.4 feet
f. Inlet Structure Top Elevation	
Primary	3,390.0 feet
Auxillary	3,390.1 feet
g. Grillage Invert	
Primary	3,375.0 feet
Auxillary	3,375.1 feet
h. Bottom of Inlet Structure	
Primary	3,360.2 feet
Auxillary	3,355.0 feet

3. Reservoir

a. Length of Normal Full Pool (approx.)	8 miles
b. Surface Area (at full pool)	3,700 acres

4. Storage

a. Total Storage (at dam crest)	127,655 acre-feet
b. Active Storage (at spillway crest)	79,071 acre-feet
c. Surcharge Storage	48,584 acre-feet
d. Dead Storage	711 acre-feet

5. Hydrology

100-year Peak Inflow	15,070 cfs
Outflow Design Flood (pool at 3,440.0 feet)	100,000 cfs
Probable Maximum Flood	
Summer	108,200 cfs
Spring	382,000 cfs
Max. Combined Spillway Capacity (pool at dam crest)	159,200 cfs

6. Embankment

a. Type	Zoned earthfill
b. Maximum Height	93 feet
c. Crest Length	1,824 feet
d. Crest Width	35 feet
e. Downstream Slope	1v on 2.25h slope from crest down to a 40-foot wide berm at elevation 3,392.4, 1v on 2.25h slope down to a 60-foot wide berm at elevation 3,384.4, and 1v on 3h slope to the toe

f. Upstream Slope	1v on 3h with 33-foot berm at elevation 3,384.4 feet

7. Primary Outlet Works

a. Inlet Structure	
Size	22.67 feet x 25 feet
Height	29.75 feet
Trash Racks	On front, both sides and top
Bulkhead Gate	9 feet wide x 9 feet high
b. Tunnel	
Upstream of Gates	Circular reinforced concrete pipe, 9 feet diameter
Downstream of Gates	Straight legged horseshoe reinforced concrete, 9 feet wide x 9 feet high
c. Gate Tower	
Type	Wet upstream well and dry downstream tower
Size	21.33 feet x 13 feet
Height	85.3 feet
Top Floor Elevation	3,445.5 feet
Maintenance Pit Elevation	3,433.5 feet
Bottom Floor Elevation	3,375.7 feet ±
Invert Elevation	3,360.2 feet
Air Vents	
Operating Gate Well	Three 24 inch diameter vents
Emergency Gate Well	One 18 inch diameter vent
d. Gates	
Emergency Gate	Fixed wheel gate, 4.5 feet wide by 7.5 feet high
Float Switch Elevation (emergency gate)	3,395.0 feet
Operating Gate	Bonneted slide gate, 4.5 feet wide by 7.5 feet high
Control	Hydraulic operator with manual override system
e. Capacity	1,642 cfs (design)
f. Tunnel Exit	
Width	9 feet
Drain	8-inch diameter with flap gate
Flipbucket End Elevation	3358.5 feet

8. Auxiliary Outlet Works

a. Inlet Structure	
Size	29.5 feet x 26 feet
Height	35.5 feet
Trash Racks	On front, both sides and top
Bulkhead Gate	10 feet wide x 37 feet high
b. Tunnel	16-foot diameter horseshoe-shaped, reinforced concrete tunnel (both upstream and downstream of the gate chamber)
c. Gate Tower	
Type	Wet upstream well and wet downstream well
Size	12 feet x 17.5 feet (approx.)
Height	89.35 feet
Top Floor Elevation	3,445.5 feet
Maintenance Pit Elevation	3,433.5 feet
Invert Elevation	3,356.15 feet
Air Vents	
Operating Gate Well	One 36 inch diameter vent
Emergency Gate Well	One 18 inch diameter vent
d. Gates	
Emergency Gate	Fixed wheel gate, 4.5 feet wide by 7 feet high
Float Switch Elevation (emergency gate)	3,395.0 feet
Operating Gate	Cast iron sluice gate, 4.5 feet wide by 7 feet high
Control	Hydraulic operator with manual override system
e. Capacity	1,603 cfs (design)
f. Tunnel Exit	
Width	16 feet
Drain	8 inch
End Wall Elevation	3,359.8 feet
Flipbucket End Elevation	3,354.4 feet

9. Principal Spillway

a. Control	150 feet wide, 4-cycle labyrinth weir
b. Width	150 feet which tapers to 100 feet (hourglass configuration)
c. Length	560 feet
d. Labyrinth Weir	
Crest Elevation	3,428.4 feet
Invert Elevation	3,416.4 feet
Number of cycles	4
Effective crest length	668 feet
Ice Nose	
Length	10 feet
Elevation	3,416.66 to 3,422.67 feet
e. Capacity	
Pool at 3440.0 feet	38,800 cfs
Pool at Dam Crest (Elev. 3444.0)	50,000 cfs
f. Flip Bucket	
End Elevation	3,380.0 feet
Width	100 feet

10. Emergency Spillway

a. Control	Stair step chute with ogee crest
b. Width	650 feet wide
c. Approach Apron	650 feet x 80 feet
d. Stair Step Chute	
Material	Roller compacted concrete base with conventional concrete encasement
Slope	1v by 2.25h
Steps	22 steps, 6.75 feet wide by 3 feet high
e. Capacity	
Pool at 3440.0 feet	61,200 cfs
Pool at Dam Crest (Elev. 3444.0)	109,200 cfs

f. Stilling Basin

Size	650 feet x 87.5 feet
Invert elevation	3,359.75 feet
Material	RCC 11 feet thick
End Sill Top Elevation	3,362.25 feet
End Sill Cap Height	5 feet 3 inches

11. Bridge

a. Width	26 feet
b. Overall Length	114 feet

OPERATING PROCEDURES

The association manages and operates the Tongue River Reservoir to provide an adequate supply of irrigation water to meet contracts with the water users without exceeding safe storage or flow levels.

DAM OPERATOR

The responsibility of the daily operations of the dam and reservoir rest with the association and its dam operator. The dam operator has the general authority to operate the reservoir to meet the association goals of providing an adequate supply of irrigation water to meet water user's contracts without exceeding safe storage and flow levels.

Specific responsibilities of the dam operator are as follows:

1. Operate the mechanical features of the outlet works
2. Coordinate the filling of the reservoir and the release of water
3. Notify the SWPB of unusual occurrences such as vandalism, impending floods, excessive seepage, damage to the spillways or gates, and electronic or hydraulic equipment malfunctions
4. Perform various maintenance tasks
5. Monitor the weather
6. Monitor the seepage

Typically, the out-going operator, association, and SWPB train a new operator. The dam operator's training focuses on the mechanical operation and electronic operation of the gates, measurement of the storage level, measurement of the rate of water release, observation of unusual conditions, and record keeping.

The dam operator is normally available daily to observe the dam and perform operating functions during the times of rapid filling and irrigation seasons, the operator is at the dam three to five times per week. At other times, the operator visits the dam weekly or monthly at other times of the year.

Communications among the dam operator, the association, and the SWPB usually takes place by telephone. Although not routinely available, radio communication may be established during emergencies or unusual occurrences so the dam operator can speak directly with county authorities and communicate indirectly with the SWPB (see **Tongue River Dam Emergency Plan**). There is a telephone in the primary gatehouse that the dam operator could also use in an emergency.

METHOD AND SCHEDULE OF OPERATION

The association's goal is to have the reservoir full before contract holders start putting in calls for water.

The date irrigation releases begin varies from year to year, with May 1 usually being the earliest. Irrigation releases usually end by September 30, as specified in the water purchase contracts. The actual dates that releases begin and end depend on the year's actual climatological and hydrological conditions.

As part of the Water Rights Compact between the State of Montana and the Northern Cheyenne Tribe, an Operating Plan For The Tongue River Reservoir has been adopted, dated May 2, 2002. The plan outlines general procedures for operating the reservoir so that the State can met its obligations under the Northern Cheyenne-Montana Compact and fulfill its water marketing contracts. A copy of the plan is in Appendix A.

Maximum Winter Storage: The maximum reservoir elevation for winter storage is 3,417.5 feet with 45,000 acre-feet of storage. This winter maximum helps prevent damage to the riprap and embankment from wind-driven waves and ice.

Minimum Winter Storage: The minimum reservoir elevation for winter storage is 3,396 feet with 10,800 acre-feet of storage. This winter minimum helps prevent ice damage to the inlet structure for the outlet works, minimizes water quality problems, and helps to maintain the fishery.

Minimum Outlet Discharge: Pursuant to the Operating Plan (Appendix A), the minimum flow to be maintained at the dam outlet to help maintain the fishery in Tongue River will generally be the inflow or 175 cfs, whichever is less. Cutting outflows to below the minimum will be allowed only as needed to accommodate necessary dam safety inspections, maintenance, drought conditions, or other emergency purposes.

Winter Operation of Tunnels: The winter outflow from the reservoir should be spilt between the two tunnels. The flow from the auxiliary outlet should be enough to cover the end wall in the tunnel. This flow should be about 60 cfs. The flow through both of the tunnels during the winter months will help to control freeze-thaw damage to the concrete and help to prevent the buildup of ice blocks in the tunnels.

SAFE DRAWDOWN

Embankment stability was investigated by the U. S. Bureau of Reclamation in 1985 during an investigative study. It was determined that under a sudden drawdown condition from PMF level to critical pool elevation (3,380 feet), the upstream slope of the embankment would have a safety factor of 1.3. Therefore, the stability of the existing embankment is not a concern during normal and emergency operations.

GATE OPERATION

The maximum combined capacity of the two outlet works is 3,245 cfs at normal full pool (elevation 3,428.4 feet). The outlet works are intended to be used for controlling the release of irrigation water and not for providing emergency flood relief.

The maximum opening for the primary operating gate is 7.5 feet and the auxiliary operating gate is 7.0 feet. Openings in excess of these amounts may damage a gate, gate frame, gate stem, or the hydraulic cylinder. The gate opening is measured by monitoring devices on the gates and is shown as an electronic digital readout on the gate control panel box as a percent (%) of full open. The gate control systems are designed to stop the gates automatically when the gates are 100% open or closed.

Operating Gate -- Normal Procedures: Listed below are the steps to be used for normal operation of the downstream gate (Gate #1). These procedures apply to the downstream gate in both outlets.

1. Check that the power is turned on. Normally the power is on at all times. This is necessary so the controls continue to function, and therefore maintain system and emergency accumulator pressure as well as panel and hydraulic heaters.

   If the power is off, turn power on.
   (a) There is an electrical switch box for the gate operating control panel. This must be turned on.

   (b) Turn "Master Control Panel Power" switch to "ON" (upper right portion of the control panel)

   (c) Turn "Control Power" switch to "On" (lower left portion of the control panel)

   (d) PLC will initialize and display should read "*Sorenson Governor Gate Control System*"

(e) When the power is turned on, one of the pumps will turn on to pressurize the system. The gates will not operate until the system has been pressurized. Once pressurized, the pump will turn off. The system is now ready for operation.
There are two pumps in each gatehouse, which alternate running each time the system is turned on.

2. Make sure the key lock switch is in the "normal" position, not the "maintenance" position (gates will not operate from the control panel when the switch is in the "maintenance" mode).
3. Push the open or close button for Gate #1 (Operating Gate) to adjust gate.
4. There is an indicator panel to the right of the control panel that shows the percent open for each gate. When the desired percent open is reached, push the stop button. Minor open/close adjustments may need to be made to get the desired percent open for the gates. The pump will automatically shut down once the gate has stopped moving and the hydraulic system pressure is at proper standby levels.
5. Leave the power on, because the system will automatically make adjustments in the system if there is any bleed off of the hydraulic fluid.

NOTE: The auxiliary operating gate (cast iron sluice gate) will chatter, bang and vibrate at certain gate openings. The gate should not be left in this position, but the opening increased or decreased until the noise and vibration stop. Failure to control the noise and vibration could cause damage to the gate system.

Emergency Gate -- Normal Procedures: Listed below are the steps to be used for normal operation of the upstream fixed wheel emergency gate (Gate #2). These procedures apply to the upstream gate in both outlets.

1. **The emergency gate (Gate #2) is to be either fully opened or fully closed. It is not designed to regulate flows.**
2. **Downstream operating gate must be closed before operating the emergency gate.**
3. Check that the power is turned on. Normally the power is on at all times.

If the power is off, turn power on. See Operating Gate -- Normal Procedures. Follow same power up procedures.

4. Make sure the key lock switch is in the "normal" position, not the "maintenance" position.
5. Gate Opening Procedure

   Initial Gate Position: *Downstream operating gate closed. Emergency gate full closed under full unbalanced water pressure.*

   (a) Push the "OPEN" button for Gate #2 (Emergency Gate) to adjust gate.
   (b) Watch position Indicator. Number on Position Indicator digital display should begin to increase.
   (c) Gate will automatically stop at 3% open ±1%.
   (d) Look down emergency gate shaft to confirm it is filling with water.
   (e) When the water level reaches the float switch inside the emergency gate shaft, the PLC display will read "Water level is at float wait for timer - 3 minutes".
   (f) Press "Alarm Ack" button on PLC display to shut off alarm.
   (g) When water pressure across the gate has equalized, the PLC display will read " *Water Column Full, OK to Continue*".
   (h) Press "Alarm Ack" button on PLC display to shut off alarm.
   (i) Press the "OPEN" button.
   (j) Watch Position Indicator digital display, it should begin to increase.
   (k) Gate will stop automatically when full open.

When opening the emergency gate from the 100% closed position, the gate will open to about 3% open, then stop. There is a crack opening system in place that limits the control of the gate. Once the gate has been opened about 3%, the system will shut down while the tower and tunnel are filled with water. There is a float switch at about elevation 3395 that will turn on a timer when the water reaches the float switch. The timer is set for three minutes. Once the 3 minutes are up, the LED display on the control panel will show "Water Column Full, OK to Continue".

The emergency gate can be closed during the crack opening cycle, but not opened.

6. Gate Closing Procedure

   Initial Gate Position: *Downstream operating gate closed. Emergency gate full open. (This operation can also be performed in the event of an emergency when the downstream regulating gate is stuck in a partial open position)*

   (a) Press the "CLOSE " button.
   (b) Watch position indicator digital display, number should decrease.
   (c) Gate will stop automatically when full closed.

7. The emergency gate when in the open position should be stored with one gate stem removed and one stem raised (hydraulic cylinder in up position) with the short (12") maintenance stem between the cylinder and the full length stem. To remove a stem, the maintenance procedures (Appendix C) should be followed. Once one stem has been removed and the gate has been raised one stem, the dogging device should be engaged. The bottom of the gate will be approximately eight (8) feet above the top of the tunnel opening. This is to prevent possible turbulence from damaging the gate.

8. Leave the power on. This is necessary to maintain system and emergency accumulator pressure as well as panel and hydraulic heaters.

Manual Gate Procedures (Both Hydraulic Pumps Fail):

Listed below are the steps to be used for manual operation of the operating gate (Gate #1) and the emergency gate (Gate #2) if both hydraulic pumps fail. Prior to proceeding with the manual procedures, try resetting the pumps. There is a reset button for each pump on the control panel. Push each reset button. This may reactivate each pump. If the pumps cannot be reactivated, follow the procedures described below. These procedures apply to the gates in both outlets.

1. Utilize accumulators to move gates.
   (a) Open Operating Gate (Gate #1)
      Press gate one open button. Gate will open, notice that accumulator and system pressure will decrease as accumulators lose pressure. To stop press stop button.

- (b) Close Operating Gate (Gate #1)
  Press gate one close button. Gate will close, notice that accumulator and system pressure will decrease as accumulators lose pressure. To stop press stop button.
- (c) Open Emergency Gate (Gate #2)
  Press gate two open button. Gate will open, notice that accumulator and system pressure will decrease as accumulators lose pressure. To stop press stop button.
- (d) Close Emergency Gate (Gate #2)
  Press gate two close button. Gate will drift closed, system pressure will not decrease as gate falls under its own weight. To stop press stop button.

2. Utilize hand pump to move gates (accumulators have lost pressure).
   - (a) Open Operating Gate (Gate #1)
     Isolate all accumulators by closing the valve located at bottom of each vertical accumulator (item 20 on hydraulic schematic). Press open gate one button. Solenoid one will shift. Insert manual hand pump handle into hand pump and pump handle up and down, system pressure will raise and gate will move open. To stop, press the stop button.
   - (b) Close Operating Gate (Gate #1)
     Isolate all accumulators by closing the valve located at bottom of each vertical accumulator (item 20 on hydraulic schematic). Press close gate one button. Solenoid two will shift. Insert manual hand pump handle into hand pump and pump handle up and down, the system pressure will raise and gate will close slowly. To stop, press the stop button.
   - (c) Open Emergency Gate (Gate #2)
     Isolate all accumulators by closing the valve located at bottom of each vertical accumulator (item 20 on hydraulic schematic). Press open gate two button. Solenoid three will shift. Insert manual hand pump handle into hand pump and pump handle up and down, system pressure will raise and gate will move open. To stop, press the stop button.
   - (d) Close Emergency Gate (Gate #2)
     Press gate two close button. Gate will drift closed, system pressure will not change as gate falls under its own weight. To stop press stop button

Manual Gate Procedures (Loss of Site Power): Listed below are the steps to be used for manual operation of the operating gate (Gate #1) and the emergency gate (Gate #2) when power is lost at the site. These procedures apply to the gates in both outlets. Manual operation is required if electricity is lost, or some other mechanical or electrical failure occurs.

1. Utilize accumulators to move gates.
   (a) Open Operating Gate (Gate #1)
   Manually shift the **Gate One** valve by pressing on **Sol 1** spool with thumb or screwdriver (press on left side of spool towards the right direction). You will hear hydraulic fluid pass through the valve. Gate will move immediately, and accumulator pressure will start to decrease slowly. To stop release spool.
   (b) Close Operating Gate (Gate #1)
   Manually shift the **Gate One** valve by pressing on **Sol 2** spool with thumb or screwdriver (press on right side of valve towards the left direction). You will hear hydraulic fluid pass through the valve. Gate will move immediately, and accumulator pressure will start to decrease slowly. To stop release spool.
   (c) Open Emergency Gate (Gate #2)
   Manually shift the **Gate Two Open** valve by pressing on **Sol 3** spool with thumb and turning to release spool. Manual override will pop out. Gate will move immediately, and accumulator pressure will start to decrease slowly. To stop, press manual override back in and turn to lock in place.
   (d) Close Emergency Gate (Gate #2)
   Manually shift the **Gate Two Close** valve by pressing on **Sol 4** spool with thumb and turning to release spool. Manual override will pop out. Gate will move immediately, gate falls under its own weight therefore system pressure should not decrease. To stop, press manual override back in and turn to lock in place.

2. Utilize hand pump to move gates (accumulators have lost pressure). This operation will require two people.
   (a) Open Operating Gate (Gate #1)
   Isolate all accumulators by closing the valve located at bottom of each vertical accumulator (item 20 on hydraulic schematic). Manually shift the **Gate One** valve by pressing on **Sol 1** spool with thumb or

screwdriver (press on left side of valve towards the right direction). Insert manual hand pump handle into hand pump and pump handle up and down, system pressure will raise and gate will move open. To stop, release spool.

(b) Close Operating Gate (Gate #1)

Isolate all accumulators by closing the valve located at bottom of each vertical accumulator (item 20 on hydraulic schematic). Manually shift the **Gate One** valve by pressing on **Sol 2** spool with thumb or screwdriver (press on right side of valve towards the left direction). Insert manual hand pump handle into hand pump and pump handle up and down, the system pressure will raise and gate will close slowly. To stop, release spool.

(c) Open Emergency Gate (Gate #2)

Isolate all accumulators by closing the valve located at bottom of each vertical accumulator (item 20 on hydraulic schematic). Manually shift the **Gate Two Open** valve by pressing on **Sol 3** spool with thumb and turning to release spool. Manual override will pop out. Insert manual hand pump handle into hand pump and pump handle up and down, system pressure will raise and gate will move open. To stop, press manual override back in and turn to lock in place.

(d) Close Emergency Gate (Gate #2)

Manually shift the **Gate Two Close** valve by pressing on **Sol 4** spool with thumb and turning to release spool. Manual override will pop out. Gate will move immediately, gate falls under its own weight therefore system pressure should not decrease. To stop, press manual override back in and turn to lock in place.

Emergency Gate -- Maintenance Procedures: Removal of the emergency gate from the gate shaft for maintenance activities should only be done with SWPB staff onsite. The procedures for removing and reinstalling the emergency gate is described in Appendix C.

INFLOW AND OUTFLOW MONITORING

Current inflows into the reservoir and outflows from the reservoir can be found under the Yellowstone River Basin portion of the following USGS internet site:

http://montana.usgs.gov/rt-cgi/gen_tbl_pg

USGS gage 06306300, Tongue River at State Line, monitors current inflows into the reservoir. The gage is located on the left bank one mile north of the Montana-Wyoming state line and 1.4 miles southeast of Decker, MT.

USGS gage 06307500, Tongue River at Tongue River Dam, monitors current outflows from the reservoir. The gage is located on the left bank 0.5 miles downstream of the dam.

STORAGE DETERMINATION

In the primary gate house there is a LED display of the reservoir elevation located on the gate operating panel. This information can also be accessed by SWPB staff from off-site via a computer modem.

Storage in the reservoir and elevation of the reservoir surface can also be determined by taking a slope measurement at the boat ramp at the Pee Wee Point North campground. Measure in feet from the 0+00 point, located at the top center of the boat ramp slab, to the water surface. The alignment follows the center of the slab with distances marked in the concrete every 25 feet. Once the slope distance is determined, the elevation of the reservoir surface and the storage can then be found using the Slope Distance-Elevation-Storage Table in Appendix B.

WEATHER MONITORING

The dam operator monitors weather conditions through local weather forecasts and the National Weather Service (NWS). NWS computer information is monitored by the SWPB during spring runoff and at other times. This information includes major stream gage readings, past 24–hour readings on small stream gages, past 24–hour weather summary, and Snotel sites information.

If severe flooding is anticipated, the NWS Billings Office **(800-240-4596 or 406-652-2314)** should be requested to make "forecast points" of the USGS gage 06306300, Tongue River at State Line. If this request is adopted, NWS will provide peak flow, storm duration, runoff duration (above base flow), and total volume flood forecasts for these two stream gauges as conditions warrant.

SNOTEL Sites: Current snow water equivalent and total precipitation can be monitored at seven SNOTEL sites located above the reservoir -- Big Goose, Bone Springs, Burgess Jct., Dome Lake, Sucker Creek, and Tie Creek. The information for these six sites can be accessed under the Tongue River Basin (Wyoming) portion of the following USDA internet site:

ftp://ftp.wcc.nrcs.usda.gov/data/snow/update/mt.txt

Additional information about historical snowpack, precipitation, maps and graphs can be accessed at the following internet site:

http://www.mt.nrcs.usda.gov/swcs/snow/snow.html

INTERACTION WITH OTHER DAMS

There are no major dams upstream or downstream of the Tongue River Dam. Therefore, interaction with other dams is not a concern in the normal operation of the Tongue River Reservoir.

EMERGENCY

If it appears that the Tongue River Dam is about to breach, or during emergency operations, the dam operator will initiate the **Tongue River Dam Emergency Action Plan.**

INSPECTION AND MONITORING

The SWPB inspects the dam annually. Appendix D includes an example of the SWPB Inspection Report Form. In addition to annual inspections, SWPB personnel will inspect the dam embankment and reservoir during and after heavy runoff, severe rainstorms, and windstorms, during high storage periods, and after an earthquake. The embankment and spillways are monitored by instrumentation.

STRUCTURAL FEATURES INSPECTION

Structural features include the dam embankment. gatehouses, outlet works, spillways, drains, seepage measurement structures. The SWPB will inspect these structures annually as part of its inspection program.

Items to be checked or noted include, but are not limited to, the following:

1. Embankment
    a. Erosion gullies in dam faces
    b. Groin areas
    c. Damage from burrowing animals or vegetation
    d. Displacement or loss of riprap protection
    e. Displacement of fill, sink holes, slumps, or other items
    f. Any seepage on downstream face or base of embankment
2. Gatehouses and Flume Vault – any damage or vandalism
3. Outlet Works
    a. Any differential settlement or movement resulting in cracking of the conduits
    b. Erosion of gate seals or concrete by cavitation immediately downstream of the gates, tunnel floor and

sides in the transition zones, and areas immediately downstream of the gate

c. Major seepage of water into the conduit

d. Deterioration of exposed concrete due to freeze/thaw cycles or sulfate reactions

e. Operation of all gates through a full cycle

f. Protective coating on metal work

g. Unobstructed operation of the air vents

h. Corrosion or pitting of any metal

i. Proper care of electrical and hydraulic equipment

j. Tower ladders

k. Condition of warning buoys and buoy system

m. Hydraulic leaks

4. Spillways
   a. Plugging of drains
   b. Cracking or movement of concrete
   c. Spalling of concrete or loss of joint material
   d.. Deterioration of walls or buildup of debris on walls
   e. Blockage of the spillway or outlet channels
   f Condition of bridge abutments, bridge deck, and guard rails
   g. Condition of panels, cracks in steps, and any movement
5. Drains
   a. Plugging of drains
   b. Sediment in drains
   c. Any plugging of flumes, weirs, and outlets and vandalism or damage to these items

RIPRAP INSPECTION

The riprap along the front face of the dam embankment should be at least **36** inches thick. Immediately after the occurrence of high water, SWPB will observe the riprap and determine if additional riprap is needed.

SEEPAGE

Right Abutment Area: Seepage has been observed flowing in the coulee about 200 yards downstream from the dam. A "V-notch" weir has been installed to measure a majority of the seepage that is flowing down the coulee. The flow in the coulee was first observed following the original first filling of the reservoir. The flow through the weir fluctuates (flow increases or decreases with an increase or decrease in the reservoir elevation) with the change in reservoir elevation. The flows appear to be increasing over the historical flows that have been measured, but the reservoir is now being operated at higher elevations than in the past. The maximum recorded flow in 2000 was about 330 gpm.

Seepage is now appearing on the road both upstream and downstream from the right abutment coulee and from the cut along the right side of the road. This seepage had not been observed prior to rehabilitation of the dam.

Standing seepage water is located in the old stream channel below the toe of the dam near the right abutment. In 1996, water was seen percolating from the bottom of the seepage pond. The percolating water looked like a sand boil, but there was no buildup of material around the exit point. The percolating water probably came from the toe drain, which exited in the channel near this location (this drain now exits through the flume vault). The percolating water was observed again during the annual inspection in November, 2003. This area is checked for changes during all inspections.

Seepage has been observed on the road above the original stream channel, in approximate alignment with the original toe drain. The seepage consisted of standing water, but no flowing water has been seen. No seepage has been observed in this area since the rehabilitation of the dam.

Left Abutment Area: The left abutment area adjacent to the tailrace area has a high wall and a coal and clinker seam exits in the wall. The coal and clinker seam seeps a considerable amount of water. Seepage has been observed exiting the abutment wall since the original first filling of the reservoir. The amount of flow fluctuates with the reservoir elevation. A "V-notch" weir was installed in 1999 upstream from a culvert which carries the seepage flow under the access road to the tailrace area. Most of the seepage is measured in the "V-notch" weir, but some of the seepage probably flows through the road fill without being measured. During 2000, the maximum flow measured was about 135 gpm.

MONITORING WELLS

Monitoring wells have been installed over a number of years, with the first four open well monitoring wells installed in 1967. Since 1967, there have been additional monitoring wells installed while others have been destroyed because of construction activities.

Currently, there are 25 drill holes in the embankment and abutments of the dam with a combination of 33 monitoring points (some drill holes have more than one standpipe). Of the 33 monitoring points, there are some that are open well standpipes only (and have to be measured with a well probe), others that are vibrating wire only (no standpipe), and some that have a vibrating wire piezometer and a standpipe. Where there are vibrating wire piezometers and standpipes for the same monitoring point, comparisons have been made of the data to confirm the vibrating wire is providing accurate information.

Figure 4 (page 11) contains a map showing the location of the monitoring wells. Appendix F contains a table identifying the

33 monitoring points, depths and elevations. Soil profiles of the drill holes and details as to how the wells were constructed are also shown in Appendix F. General information about the vibrating wire piezometers and the data loggers is described in Appendix G.

SEEPAGE MONITORING

The open well standpipes, vibrating wire piezometers, weirs, flumes, drains and seepage areas are observed and monitored by the dam operator, Billings Regional Office, and SWPB during regular visits; and may be measured by the SWPB during annual inspections. The instruments are generally measured twice per month from May 1 to August 31, and once per month in March, April, September, and October. Measurements may be taken during the winter months (November, December, January, February) depending on weather conditions.

Discharge tables for the flumes and V-notch weirs are in Appendix B. Procedures for downloading the vibrating wire information from the data loggers and saving it to an Excel spreadsheet is in Appendix H.

SURVEY MONUMENT MONITORING

There are 16 survey monument points located in the concrete structures at the dam. Twelve are located on and around the primary spillway, and four are located on the emergency spillway. Additionally, there are five monuments at the slide area located upstream of the dam on the east side of the reservoir. The monuments were placed to monitor settlement and movement. The monuments are measured annually. Figure 5 (page 12) shows the location of the monuments. A description of the monument coordinates are shown in Appendix I.

SAFTY STRUCTURES

Warning buoys and a buoy system have been installed in front of the principal spillway. The purpose of the buoy system is to warn boats, water skiers, fishermen and jet skiers that the area is dangerous.

Warning signs have also been installed on the downstream channel. There are warning signs on each side of the channel and a cable with warning signs has been placed across the channel. The purpose of the signs is to warn fishermen, site seers, and boaters that the area upstream of the warning signs is dangerous.

MAINTENACE

The association is responsible for routine maintenance of the project. In addition, the SWPB may identify items that need maintenance or repair during the annual inspection.

ROUTINE MAINTENANCE

To protect the dam and keep it in good working order, the dam operator during regular visits to the dam will watch for and identify any potential maintenance requirements. As soon as a need is identified, the dam operator needs to schedule and perform the routine maintenance.

Items that may need occasional attention include, but are not limited to.

1. *Lubrication of gate hoisting mechanisms*
2. *Debris or silt in either the spillway channels or the outlet channel or on the spillway walls.* Accumulated debris that could affect the operation of these appurtenances should be removed at once. All debris should be removed at least annually.
3 *Erosion gullies on embankment and abutments.* Development of erosion gullies should be checked immediately. Gullies should be filled, compacted, and seeded. Particular attention should be paid to the groin areas and the downstream faces where four wheel drive tracks may become a problem
4. *Rodent damage.* The rodents will be removed or destroyed, and any burrow holes should be filled immediately.
5. *Upstream slope riprap.* The upstream riprap normally will be observed annually, but may occasionally need repairs because of high water or wave action.
6. V*egetative cover on downstream slopes.* Good vegetative cover will be maintained, but large brush and trees will be removed.

7. *Cleaning spillway wall tops.* Spillway wall tops should be clear of any dirt, rocks, grass, brush, and any overhanging vegetation or trees.
8. *Vegetation in spillway floor joints.* Anything growing in any of the floor joints should be removed, and then the joint sealed.
9. *Repair of the spillway joints and sealing of cracks in the spillway.*
10. *Noxious weeds.* Noxious weeds on and around the dam embankment, reservoir, and spillways should be sprayed at least on an annual basis.
11. *Weirs and Flumes.* These devices will be maintained clean of sediment and algae, kept upright, free flowing, and free of debris.
12. *Safety Devises.* The devises will be maintained and if destroyed by vandalism, shooting, or theft will be replaced immediately.

ANNUAL MAINTENANCE

The SWPB conducts annual inspections of the Tongue River Dam and reservoir. During these inspections, any items requiring annual maintenance will be identified and recorded. Items that may need annual maintenance include the dam embankment, outlet works spillways, gates, valves, riprap, roads, bridge, and gatehouses. Other routine items needing immediate attention, such as the need to remove trees or brush will also be noted.

After the inspection, the SWPB sends the association a Dam Safety Inspection Report and a Maintenance Schedule Report. These reports identify items that need maintenance and provide a schedule of the maintenance tasks needing to be completed. The association is responsible for performing the maintenance items within the times specified. Once maintenance tasks are completed the association signs the Maintenance Schedule Report and returns the report to the SWPB.

The dam operator or association members may perform the maintenance tasks. However, major repairs will likely to be handled by a contractor. The SWPB may assist in contracting for repairs and may supervise the repair work.

HYDRAULIC SYSTEM MAINTENANCE

A logbook is maintained in each gatehouse. Anytime any adjustments, maintenance or repairs are made to the hydraulic gate system, a note should be made in the logbook of the activity. This would include, but is not limited to, changing the oil filter, fixing oil leaks, adding hydraulic oil, taking oil samples, adding nitrogen to the system, replacing panel lights, etc.

The indicator panel inside each gate operating panel has a number of "F" buttons that can be pushed to obtain certain information. The "F" buttons provide the following information:

F1- % gate opening for each gate.
F2- not used.
F3- number of cycles that pump #1 has operated and the amount of time that it has been on.
F4- number of cycles that pump #2 has operated and the amount of time that it has been on.

To get the display, just push the "F" button. The other buttons in the panel are not used.

Check Operating Panel Lights: To check the lights inside the operating panel, press both stop buttons at the same time. This will turn on all the light bulbs in the panel. If a light does not turn on, it should be replaced. Spare bulbs are maintained in the bottom of the panel box and in the desk in the office. The replacement bulb is: CR104PXA54 GE.

Depressurize Hydraulic System: If there are leaks or other problems with the system, the system should be depressurized first prior to any work being performed. First turn off the power to the system and "lock out" the power. Slowly crack the drain valve on each accumulator (item 46 on hydraulic schematic) which will depressurize the oil in each accumulator. This can be confirmed by watching the accumulator pressure gage. The balance of the system will still be pressurized -- see system pressure gage. A hydraulic oil line must be loosened **slowly** to relieve the system pressure. This can be confirmed by watching the system pressure gage. Once the system pressure is removed, the system can then be worked on safely.

Changing The Oil Filter: The oil filter on the hydraulic system should be changed every 12 months. It is located in the blue piping cabinet to the left side of the control panel. The correct filter is: Parker Filter #926169 10C or (PFS 100002 000).

(1) Turn off the power. This prevents the pump from coming on.

(2) Place a small bucket under the filter. There is about 1 quart of oil on top of the filter that will leak from the system.

(3) Remove the filter. A filter wrench may be needed.

(4) Once the filter has been removed, remove the old rubber gasket that goes between the filter and the filter attachment point.

(5) Place a new rubber gasket into the retainer where the old rubber gasket was located. Make sure to place hydraulic oil on the rubber gasket before replacing it.

(6) Put on the new filter.

NOTE: May need to close the pressure gage valve to remove and replace the filter.

Changing Hydraulic Fluid: The hydraulic fluid in the gate operating system should be changed when it becomes dirty, contains to much water, or oil additives break down. An oil sample from both the primary and auxiliary hydraulic systems should be taken yearly and sent to CTC Analytical Services in Atlanta, GA for testing (800-394-3669). Ten prepaid sample kits cost about $300. Take the samples from the drain valve on the oil tank. When taking an oil sample, discard the initial oil (maybe a cup) to come out of the valve. This oil will mostly likely contain dirt from valve and drain piping. CTC will return a report with the test results and will recommend when the oil should be changed.

When it becomes necessary to change the oil, it is not necessary to depressurize the system. Only the oil in the tank will be changed. Before draining the oil, mark the oil level on the site gage. When refilling the tank with new oil, only fill to the same mark. The hydraulic fluid to use is 32 weight (viscocity). The tank holds 150 gallons. To estimate how much oil to purchase, use a percentage of the tank filled. For example, if the oil level is ¾ full, then oil needed is 150 X .75 = 112 gallons.

Nitrogen Precharge Check: The nitrogen in the two large horizontal bottles is used to operate the gates in case of a power failure or pump failure. The nitrogen precharge should be between 1500 and 1550 psi.

To check the nitrogen precharge, first turn off the power to the system and "lock out" the power. Slowly crack the drain valve on each accumulator (item 46 on hydraulic schematic) which will depressurize the oil in each accumulator. This can be confirmed by watching the accumulator oil pressure gage (item 21 on hydraulic schematic). As the oil pressure falls watch the accumulator pressure gage. Watch for the final reading before the pressure drops off to zero. It should stay around the precharge level then drop off quickly right to zero. That pressure just before the drop off is the nitrogen precharge.

Once the accumulator oil pressure is "0", the nitrogen precharge pressure can also be determined by reading the accumulator gas pressure gage (item 50 on hydraulic schematic).

If the precharge is below 1500 psi, additional nitrogen will need to be added to the system. To recharge the two horizontal nitrogen tanks, the following items will be required: external nitrogen tanks (which can be obtained in Sheridan), a regulator for the external tanks and a charging kit to hook the external nitrogen tank to the horizontal tanks. The last two items (regulator and charging kit) are onsite in a wooden storage box on the floor of the primary gatehouse.

(1) Turn off the power to the system and "lock out" the power.

(2) Slowly crack the drain valve on each accumulator (item 46 on hydraulic schematic) which will depressurize the oil in each accumulator. This can be confirmed by watching the accumulator oil pressure gage.

(3) When accumulator oil pressure gage (item 21 on hydraulic schematic) is "0", close accumulator drain valves.

(4) Secure external nitrogen tank to the wall.

(5) Hook up external nitrogen tank to the system. The regulator should be mounted to the external tank and the charging kit is used to connect the output side of the regulator to the horizontal tanks.

(6) The accumulator gas pressure gage (item 50 on hydraulic schematic) will indicate the nitrogen precharge pressure.

(7) Turn the needle check valve (bike type valve) on the horizontal tank to the right (clockwise) which opens the valve.

(8) The valve on the regulator should be backed out. Open the valve on the external tank which will pressurize the supply side of the regulator. Slowly close the valve on the regulator which will increase the output pressure gage on the regulator.

(9) To get nitrogen to flow from the external tank to the horizontal tank, the output pressure on the regulator must be higher (50 to 100 psi) than the precharge pressure. As the pressure in the horizontal tanks increases, the output pressure on the regulator must be increased.

(10) To change the external tank, back out the needle check valve (bike type valve) to isolate the horizontal tank, close the valve on the external tank, and loosen regulator slowly to release pressure on the supply side of the regulator.

(11) Repeat steps (4) through (10) until the pressure in the horizontal tanks is between 1500 and 1550 psi.

RECORD KEEPING

The SWPB maintains records, including photographs, of all inspections and maintenance requirements. These records also include seepage monitoring observations. Anyone who wants to review these records may do so in the SWPB's office at the Department of Natural Resources and Conservation in Helena.

The dam operator will keep records of the reservoir elevations, or measurements, and any unusual conditions. These records may be reviewed at the dam operator's house or at the office in the primary gatehouse.

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APPENDICES

APPENDIX A

OPERATION PLAN

OPERATING PLAN FOR THE TONGUE RIVER RESERVOIR

This plan has been developed to fulfill a directive in the Reserved Water Rights Compact between the State of Montana, the United States, and the Northern Cheyenne Tribe (Compact), which specifies that the five-member Advisory Committee develops an Operating Plan for the Tongue River Reservoir consistent with purposes of the Compact. The plan outlines general procedures for operating the Tongue River Reservoir so that the State of Montana through the Department of Natural Resources and Conservation (DNRC) can meet its obligations under the Compact and fulfill its Water Marketing contracts with the Tongue River Water Users' Association (TRWUA), and the existing 7,500 acre-feet contract with the Bureau of Indian Affairs for the Northern Cheyenne Tribe. The guidelines include procedures for storing and releasing contract water, passing direct flow rights, and for the delivering of up to 20,000 acre feet annually of stored water for use by the Northern Cheyenne Tribe (NCT). The Plan also contains recommended minimum pool levels, downstream release rates, and recommendations regarding water for fish and wildlife purposes.

Attached to the Plan are appendices that will be referenced when operating the Reservoir including: (1) detailed reservoir statistics and operational facts, (2) the DNRC Manual for Operation and Maintenance, (3) the Emergency Action Plan, (4) the Tongue River Reservoir Operating Guide provided by the Natural Resources Conservation Service, (5) the Tongue River Water Modeling Study, Final Report, July 20, 1990, or any revision agreed to by the Compact Parties, 6) a list of water contracts from the NCT and TRWUA, 7) a list of senior downstream water rights, and 8) the Compact.

I. Advisory Committee Guiding Principles

A. Goals:

1. Fulfill the directives of the Compact.
2. Ensure that obligations to the NCT are fulfilled.
3. Ensure that the Water Marketing Contract with the TRWUA is met.
4. To the greatest extent possible, ensure that the Reservoir is operated in a safe, efficient, and environmentally sound manner.
5. Provide for the operation of the project for fish and wildlife purposes, depending on water availability.
6. Encourage communication between interested parties and seek to improve Plan documentation and guidelines through such interaction.

7. All Advisory Committee records, including data collected by the dam tender, shall be made available for Committee review.

B. Guidelines:

1. The Advisory Committee shall, at its annual meeting, agree upon a Reservoir operation schedule setting forth proposed uses and direct flows for the year. The DNRC or its successor, shall be responsible, consistent with the terms of the Compact and other applicable laws, for the daily operation of the Reservoir and the implementation of the Reservoir Operating Plan.
2. The Advisory Committee will meet annually, at a pre-arranged location, and periodically via conference calls.
3. A simple majority of at least three of the five Committee members, including one member from the BIA or NCT, must be present at all conference calls and meetings.
4. Meeting agendas will be developed in advance by the DNRC representative, with all members of the Advisory Committee contacted prior to the meeting so they have the opportunity to review the draft agenda and include additional agenda items.
5. Standard parliamentary procedures will be followed for all Advisory Committee meetings, including a reading of minutes from the previous meeting, agreement on the minutes, the call for motions and seconding of motions, and a verbal yes or no vote for all decisions and/or actions necessitating the full Committee's endorsement. Meeting minutes will be compiled and distributed to Committee members within 30 days. Decisions will be made by consensus if possible or by vote if necessary. Three members will constitute a majority vote for a motion to pass. A chairman will be appointed to an annual term by the Committee to conduct meetings, including call for motions, setting agendas, and general protocol.
6. Amendments to the Operating Plan will be made in March of each year, unless otherwise agreed to and arranged by unanimous consent of the Advisory Committee members. A majority vote will be required for a passage of an amendment.
7. The membership of the Advisory Committee shall be the following:
    a) One member appointed by the NCT.
    b) The elected President of the Tongue River Water Users Association.

c) The current Bureau Chief of the State of Montana DNRC State Water Projects Bureau.
d) The current BIA Superintendent, Northern Cheyenne Agency, representing the United States.
e) A fifth member to be selected by the above four members. The term of appointment for this member will be one water year (Oct.1 – Sept.30).

II. Regulation of Reservoir Levels and Outflows

A. Goals:

1. Provide operating criteria and release schedule for the upcoming water year.

2. Provide stored Compact water (20,000 AF annually) to the NCT.

3. Provide 7,500 AF of water annually under existing contract with the NCT.

4. Pass through senior downstream water rights, including the NCT's direct flow right of up to 12,500 AF.

5. Satisfy water purchase contracts.

6. Fill the Reservoir during spring runoff.

7. Protect the Reservoir intake structure from freeze-thaw damage.

8. Provide water for Reservoir and downstream fish and wildlife when available.

9. Maintain adequate carry-over storage in the Reservoir during the fall, winter, and early spring.

10. Maintain appropriate winter outflow from the Reservoir to minimize downstream icing problems.

B. Guidelines:

1. The DNRC and TRWUA will be responsible for the daily operations of the dam and Reservoir, and implementation of the Reservoir Operating Plan once it is established. The dam tender hired by DNRC and the TRWUA will monitor reservoir elevations and storage contents, and make gate adjustments at the Dam as needed. The dam tender will make visits to the Reservoir for gate adjustments to regulate outflows, including storing and releasing contract

and Compact water or for other purposes when special circumstances require. The dam tender will also submit monthly reports on dam operations to the Advisory Committee.

2. The dam tender will keep records of his visits to the project. The dam tender will record elevation and storage readings weekly from May 1 through September 30, and biweekly from October 1 through April 30, every year. Accounting for the water released to satisfy contract and Compact water is the responsibility of the TRWUA and the dam tender. When making gate adjustments, the dam tender will remain on-site long enough to ensure that the desired adjustment is achieved.

3. The dam tender will notify the TRWUA President when he/she will not be available to operate the gate. The TRWUA will then notify the DNRC State Water Projects Bureau (SWPB) Helena Office. The dam gate is to be operated by a designated DNRC employee or TRWUA back-up person when the dam tender is unavailable and when operation and maintenance work is needed at the project. The dam tender and the TRWUA President will be provided the list of the designated DNRC employees. The dam tender will immediately notify the SWPB Helena Office if there appears to be any problem with the operation of the gate.

4. By March 1 of each year, the DNRC shall evaluate reservoir storage, snowpack, streamflow, streamflow forecast, soil moisture, and the extended weather forecast/outlook. Results of DNRC's evaluation will be presented at the Advisory Committee's next scheduled meeting, but no later than March 31 of each year. If the reservoir elevation is higher than average and indications are that a wet, high-runoff spring could exist, the DNRC and TRWUA will consider increasing the outflow so that some storage capacity is available to control downstream flooding. If the reservoir elevation is lower than average and conditions indicate the potential for a dry, low-runoff spring, the DNRC will inform the Advisory Committee of the potential for a water shortage that year. The Advisory Committee will implement a storage plan to minimize the impact of such a shortage.

5. When the spring flood/runoff period has ended, the dam tender will notify the DNRC when the water users and NCT have begun to call for release of contract or Compact water. All requests for water releases by the TRWUA and the NCT will be made and coordinated through the DNRC as determined by the Advisory Committee. The TRWUA and the NCT will submit requests for water by October for the following year's water use, with as much detail as possible, including the amount, use, and timing, to be incorporated into the Tongue River Water Model.

6. During the development of the Annual Reservoir Operating Plan, the Advisory Committee will take into account the NCT's right to excess water

and exchange water as defined in the Compact and depending upon the NCT's water uses in the water year.

7. When the reservoir storage level has been drawn down to 50,000 acre feet, the DNRC will inform the Advisory Committee so they may determine how to allocate the remaining water in the Reservoir. The DNRC will establish a benchmark at this elevation.

8. The reservoir storage contents may not be drawn down below 10,800 acre-feet after September 30. All contracts will be considered satisfied when the reservoir storage reaches this level. If there is a need to draw storage contents below this level, the Advisory Committee will meet to set a revised storage level. A suggested absolute minimum pool for the Reservoir will be 10,800 acre-feet (elevation 3396.0 feet) for protection of the intake structure during winter operation.

9. The Advisory Committee recommends that the maximum preferred carry-over be 45,000 AF (elevation 3417.5 feet) in order to minimize freeze-thaw damage to the dam by allowing water to remain at the bottom of the concrete walls.

10. The recommended maximum sustainable outflow through the low-level outlet works of the Reservoir is approximately 3,300 cfs.

11. The minimum outflow of the Reservoir during the winter low flow period, from Oct. 1 to Mar. 1, will generally be the inflow or 175 cfs, whichever is less. Cutting outflows to below the minimum will be allowed only as needed to accommodate necessary dam safety inspections, maintenance, dam safety, or other emergency purposes.

12. The Reservoir Operating Plan shall provide for the operation of the project for fish and wildlife purposes depending on the availability of water on an annual basis. This provision shall not create an operational preference for fish and wildlife purposes relative to other project purposes. Minimum pool targets and minimum winter outflow rates have been set forth under guidelines 7 and 10 above. The Advisory Committee also may consider additional reservoir releases for fish spawning, or fish and wildlife enhancement when a surplus of water is available above the requirements established in the Compact.

III. Emergency Response

A. Goals:

1. Provide maximum early warning in the event of a failure of the Tongue River Dam.
2. Provide maximum early warning in the event of discharging large inflows over the spillway.
3. Minimize loss of life or property.

B. Guidelines:

1. The TRWUA and DNRC will follow the Emergency Action Plan for the Tongue River Reservoir.

IV. Maintenance

A. Goals:

1. Maintain the Dam in good condition so that it will continue to fulfill its function providing a reliable source of water.
2. Maintain the Dam in good condition so as to minimize the risk to life or property downstream of the Dam.

B. Guidelines:

1. The DNRC will operate and maintain the Reservoir in accordance with the Tongue River Reservoir Manual for Operation and Maintenance.
2. Inspections of the Dam will be in accordance with Montana State Dam Safety Guidelines.

Adopted and Effective Upon Signing By All Parties:

BY: Art Hayes Jr. 10/17/01

TONGUE RIVER WATER USERS ASSOCIATION DATE

BY: Glen McDonald 10/17/01

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION DATE

BY: Geri Small 5/2/02

NORTHERN CHEYENNE TRIBE DATE

BY: John E White 10/17/01

BUREAU OF INDIAN AFFAIRS DATE

BY: Roger Muggli 10/17/01

ROGER MUGGLI DATE

APPENDIX B

RATING CURVES AND TABLES

TABLE 1. SLOPE-ELEVATION-STORAGE TABLE

TONGUE RIVER DAM

Slope pins located at boatramp at Peewee Point.
Pins installed and elevation established during Phase 1 construction in 1996.
The 0+00 pin (brass cap) is at the top left (southwest) corner of the boat ramp.
Measurements are made down the center of the boatramp. Distances from the 0+00 point are stamped in the concrete every 25 feet.
Storage volumes from 1995 and 1996 reservoir surveys.
Storage volumes include 711 acre-feet of dead storage.

DISTANCE	ELEVATION	STORAGE
0+00	3429.76	84,351
Brass Cap	3429.74	84,274
1	3429.67	84,002
2	3429.57	84,614
3	3429.48	83,264
4	3429.38	82,876
5	3429.29	82,526
6	3429.19	82,138
7	3429.10	81,789
8	3429.00	81,400
9	3428.91	81,013
10	3428.81	80,632
11	3428.72	80,289
12	3429.62	79,909
13	3428.53	79,566
14	3428.43	79,185
Spillway	3428.40	79,071
15	3428.34	78,886
16	3428.24	78,505
17	3428.13	78,086
18	3428.03	77,705
19	3427.93	77,346
20	3427.83	76,996
21	3427.72	76,611
22	3427.62	76,261
23	3427.52	75,911
24	3427.41	75,526
25	3727.31	75,176
26	3427.20	74,791
27	3427.09	74,405
28	3426.98	74,020
29	3426.87	73,635
30	3426.77	73,285
31	3426.66	72,900
32	3426.55	72,515
33	3426.44	72,130
34	3426.33	71,745
35	3426.22	71,360
36	3426.11	70,975
37	3426.00	70,590
38	3425.90	70,240
39	3425.79	69,855
40	3425.68	69,470
41	3425.57	69,085
42	3425.46	68,700
43	3425.35	68,315
44	3425.24	67,930
45	3425.13	67,545
46	3425.03	67,195
47	3424.92	66,769
48	3424.81	66,393
49	3424.70	66,016
50	3424.59	65,640
51	3424.47	65,229
52	3424.34	64,832
53	3424.22	64,421
54	3424.10	64,011
55	3423.97	63,577
56	3423.85	63,212
57	3423.72	62,817
58	3423.60	62,452
59	3423.48	62,087
60	3423.35	61,692
61	3423.23	61,327
62	3423.11	60,962
63	3422.98	60,567
64	3422.86	60,202
65	3422.74	59,837
66	3422.61	59,442
67	3422.49	59,077
68	3422.37	58,712
69	3422.24	58,316
70	3422.12	57,951
71	3421.99	57,556
DISTANCE	ELEVATION	STORAGE

TABLE 1. SLOPE-ELEVATION-STORAGE TABLE (continued)

TONGUE RIVER DAM

DISTANCE	ELEVATION	STORAGE
72	3421.87	57,191
73	3421.75	56,826
74	3421.62	56,431
75	3421.50	56,066
76	3421.38	55,701
77	3421.26	55,336
78	3421.14	54,971
79	3421.02	54,606
80	3420.90	54,241
81	3420.78	53,876
82	3420.66	53,511
83	3420.54	53,147
84	3420.42	52,782
85	3420.30	52,417
86	3420.18	52,052
87	3420.06	51,507
88	3419.93	51,322
89	3419.81	51,010
90	3419.69	50,697
91	3419.57	50,385
92	3419.45	50,072
93	3419.33	49,760
94	3419.21	49,447
95	3419.09	49,135
96	3418.97	48,822
97	3418.85	48,510
98	3418.73	48,197
99	3418.61	47,885
100	3418.49	47,572
101	3418.36	47,234
102	3418.23	46,895
103	3418.10	46,556
104	3417.97	46,218
105	3417.84	45,879
106	3417.71	45,541
107	3417.58	45,202
108	3417.45	44,864
109	3417.32	45,525
110	3417.19	46,218
Brass Cap	3417.17	44,135
111	3417.06	43,848
112	3416.93	43,510
113	3416.79	43,145
114	3416.66	42,806
115	3416.53	42,468
116	3416.40	42,129
117	3416.27	41,791
118	3416.14	41,452
119	3416.01	41,114
120	3415.88	40,821
121	3415.75	40,533
122	3415.62	40,245
123	3415.49	39,956
124	3415.36	39,668
125	3415.23	39,380
126	3415.09	39,069
127	3414.95	38,758
128	3414.81	38,448
129	3414.68	38,159
130	3414.54	37,849
131	3414.40	37,538
132	3414.26	37,228
133	3414.12	36,917
134	3413.98	36,607
135	3413.85	36,318
136	3413.71	36,008
137	3413.57	35,697
138	3413.43	35,386
139	3413.29	35,076
140	3413.15	34,765
141	3413.02	34,477
142	3412.88	34,166
143	3412.74	33,856
144	3412.60	33,545
145	3412.46	33,235
146	3412.32	32,924
147	3412.19	32,636
148	3412.05	32,325
149	3411.91	32,051
150	3411.77	31,798
151	3411.65	31,581
152	3411.53	31,364
153	3411.41	31,147
154	3411.29	30,930
155	3411.16	30,695
156	3411.04	30,478
157	3410.92	30,261
158	3410.80	30,044
DISTANCE	ELEVATION	STORAGE

TABLE 1. SLOPE-ELEVATION-STORAGE TABLE (continued)

TONGUE RIVER DAM

DISTANCE	ELEVATION	STORAGE	DISTANCE	ELEVATION	STORAGE
159	3410.68	29,826	202	3404.64	20,136
160	3410.65	29,609	203	3404.50	19,934
161	3410.44	29,392	204	3404.36	19,732
162	3410.32	29,175	205	3404.22	19,530
163	3410.19	28,940	206	3404.09	19,343
164	3410.07	43,145	207	3403.95	19,154
165	3409.95	28,506	208	3403.81	18,989
166	3409.83	28,289	209	3403.68	18,836
167	3409.71	28,072	210	3403.54	18,671
168	3409.59	27,855	211	3403.40	18,506
169	3409.47	27,638	212	3403.26	18,341
170	3409.35	27,421	213	3403.13	18,188
171	3409.22	27,186	214	3402.99	18,023
172	3409.10	26,968	215	3402.85	17,858
173	3408.98	26,751	216	3402.71	17,693
174	3408.86	26,534	217	3402.58	17,540
175	3408.74	26,317	218	3102.44	17,375
176	3408.59	26,046	219	3402.30	17,210
177	3408.43	25,757	220	3402.17	17,057
178	3408.28	25,485	221	3402.03	16,892
179	3408.13	25,214	222	3401.89	16,727
180	3407.97	24,935	223	3401.75	16,562
181	3407.82	24,719	224	3401.62	16,409
182	3407.67	24,603	225	3401.48	16,244
183	3407.51	24,272	226	3401.34	16,079
184	3407.36	24,056	227	3401.20	15,914
185	3407.21	23,840	228	3401.06	15,749
186	3407.05	23,609	229	3400.92	15,585
187	3406.90	23,393	230	3400.78	15,420
188	3406.75	23,177	231	3400.64	15,255
189	3406.60	22,961	232	3400.50	15,090
190	3406.44	22,730	Brass Cap	3400.40	14,972
191	3406.29	22,514	233	3400.37	14,937
192	3406.14	22,298	233.9	3400.24	14,783
193	3405.98	22,067			
194	3405.83	21,851			
195	3405.68	21,635			
196	3405.52	21,404			
197	3405.37	21,188			
198	3405.22	20,972			
199	3405.06	20,741			
200	3404.91	20,525			
201	3404.77	20,323			
DISTANCE	ELEVATION	STORAGE	DISTACNE	ELEVATION	STORAGE

TABLE 2. TOTAL STORAGE IN ACRE-FEET

TONGUE RIVER RESERVOIR

Elevation	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3,374	711	711	711	711	711	741	772	802	833	863
3,375	894	905	916	927	938	949	960	971	982	993
3,376	1,004	1,029	1,054	1,079	1,104	1,129	1,154	1,179	1,205	1,230
3,377	1,255	1,280	1,305	1,330	1,355	1,380	1,405	1,431	1,456	1,481
3,378	1,506	1,531	1,556	1,581	1,606	1,632	1,657	1,682	1,707	1,732
3,379	1,757	1,782	1,807	1,833	1,858	1,883	1,908	1,933	1,958	1,983
3,380	2,008	2,045	2,081	2,118	2,154	2,191	2,227	2,264	2,300	2,337
3,381	2,373	2,410	2,446	2,483	2,519	2,555	2,592	2,628	2,665	2,701
3,382	2,738	2,774	2,811	2,847	2,884	2,920	2,957	2,993	3,030	3,066
3,383	3,103	3,139	3,176	3,212	3,248	3,285	3,321	3,358	3,394	3,431
3,384	3,467	3,516	3,566	3,615	3,664	3,713	3,762	3,811	3,860	3,909
3,385	3,959	4,008	4,057	4,106	4,155	4,204	4,253	4,302	4,351	4,401
3,386	4,450	4,499	4,548	4,597	4,646	4,695	4,744	4,794	4,843	4,892
3,387	4,941	4,990	5,039	5,088	5,137	5,186	5,236	5,285	5,334	5,383
3,388	5,432	5,493	5,554	5,616	5,677	5,738	5,799	5,860	5,922	5,983
3,389	6,044	6,105	6,166	6,228	6,289	6,350	6,411	6,472	6,534	6,595
3,390	6,656	6,717	6,778	6,839	6,901	6,962	7,023	7,084	7,145	7,207
3,391	7,268	7,329	7,390	7,451	7,513	7,574	7,635	7,696	7,757	7,819
3,392	7,880	7,953	8,026	8,099	8,173	8,246	8,319	8,392	8,465	8,539
3,393	8,612	8,685	8,758	8,832	8,905	8,978	9,051	9,125	9,198	9,271
3,394	9,344	9,417	9,491	9,564	9,637	9,710	9,784	9,857	9,930	10,003
3,395	10,076	10,150	10,223	10,296	10,369	10,443	10,516	10,589	10,662	10,735
3,396	10,809	10,901	10,993	11,086	11,178	11,270	11,362	11,455	11,547	11,639
3,397	11,732	11,824	11,916	12,009	12,101	12,193	12,285	12,378	12,470	12,562
3,398	12,655	12,747	12,839	12,932	13,024	13,116	13,208	13,301	13,393	13,485
3,399	13,578	13,670	13,762	13,855	13,947	14,039	14,131	14,224	14,316	14,408
3,400	14,501	14,618	14,736	14,854	14,972	15,090	15,208	15,325	15,443	15,561
3,401	15,679	15,797	15,915	16,033	16,150	16,268	16,386	16,504	16,622	16,740
3,402	16,857	16,975	17,093	17,210	17,328	17,446	17,564	17,682	17,799	17,917
3,403	18,035	18,153	18,271	18,389	18,506	18,624	18,742	18,860	18,978	19,059
3,404	19,213	19,357	19,502	19,646	19,790	19,934	20,078	20,222	20,366	20,510
3,405	20,655	20,799	20,943	21,087	21,231	21,375	21,519	21,664	21,808	21,952
3,406	22,096	22,240	22,384	22,528	22,673	22,817	22,961	23,105	23,249	23,393
3,407	23,537	23,681	23,826	23,970	24,114	24,258	24,402	24,546	24,690	24,835
3,408	24,979	25,160	25,340	25,521	25,702	25,883	26,064	26,245	26,426	26,607
3,409	26,788	26,968	27,149	27,330	27,511	27,692	27,873	28,054	28,235	28,416
3,410	28,596	28,777	28,958	29,139	29,320	29,501	29,687	29,863	30,044	30,224

TABLE 2. TOTAL STORAGE IN ACRE-FEET (continued)

TONGUE RIVER RESERVOIR

Elevation	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3,411	30,405	30,586	30,767	30,948	31,129	31,310	31,491	31,672	31,852	32,033
3,412	32,214	32,436	32,658	32,880	33,102	33,323	33,545	33,767	33,989	34,211
3,413	34,433	34,654	34,876	35,098	35,320	35,542	35,764	35,985	36,207	36,429
3,414	36,651	36,873	37,095	37,316	37,538	37,760	37,982	38,204	38,426	38,647
3,415	38,869	39,091	39,313	39,535	39,757	39,978	40,200	40,422	40,644	40,866
3,416	41,088	41,348	41,608	41,869	42,129	42,390	42,650	42,911	43,171	43,431
3,417	43,692	43,952	44,213	44,473	44,734	44,994	45,254	45,515	45,775	46,036
3,418	46,297	46,556	46,817	47,077	47,338	47,598	47,859	48,119	48,379	48,640
3,419	48,900	49,161	49,421	49,681	49,942	50,202	50,463	50,723	50,984	51,244
3,420	51,504	51,808	52,113	52,417	52,721	53,025	53,329	53,633	53,937	54,241
3,421	54,545	54,850	55,154	55,458	55,762	56,066	56,370	56,674	56,978	57,282
3,422	57,586	57,891	58,195	58,499	58,803	59,107	59,411	59,715	60,019	60,323
3,423	60,628	60,932	61,236	61,540	61,844	62,148	62,452	62,756	63,060	63,364
3,424	63,669	64,011	64,353	64,695	64,990	65,332	65,674	66,016	66,358	66,701
3,425	67,090	67,440	67,790	68,140	68,490	68,840	69,190	69,540	69,890	70,240
3,426	70,590	70,940	71,290	71,640	71,990	72,340	72,690	73,040	73,390	73,740
3,427	74,090	74,440	74,791	75,141	75,491	75,841	76,191	76,541	76,891	77,241
3,428	77,591	77,972	78,353	78,734	79,071	79,452	79,833	80,213	80,594	80,975
3,429	81,400	81,787	82,177	82,565	82,953	83,342	83,730	84,118	84,507	84,895
3,430	85,283	85,671	86,060	86,448	86,836	87,225	87,613	88,001	88,389	88,778
3,431	89,166	89,554	89,943	90,331	90,719	91,107	91,496	91,884	92,272	92,661
3,432	93,049	93,467	93,884	94,302	94,720	95,137	95,555	95,973	96,390	96,808
3,433	97,226	97,643	98,061	98,479	98,896	99,314	99,732	100,149	100,567	100,985
3,434	101,402	101,820	102,238	102,656	103,073	103,491	103,909	104,326	104,744	105,162
3,435	105,579	105,997	106,415	106,832	107,250	107,668	108,085	108,503	108,921	109,338
3,436	109,756	110,204	110,651	111,099	111,546	111,993	112,441	112,888	113,336	113,783
3,437	114,231	114,678	115,126	115,573	116,021	116,468	116,916	117,363	117,811	118,258
3,438	118,705	119,153	119,600	120,048	120,495	120,943	121,390	121,838	122,285	122,733
3,439	123,180	123,628	124,075	124,522	124,970	125,417	125,865	126,312	126,760	127,207
3,440	127,655									

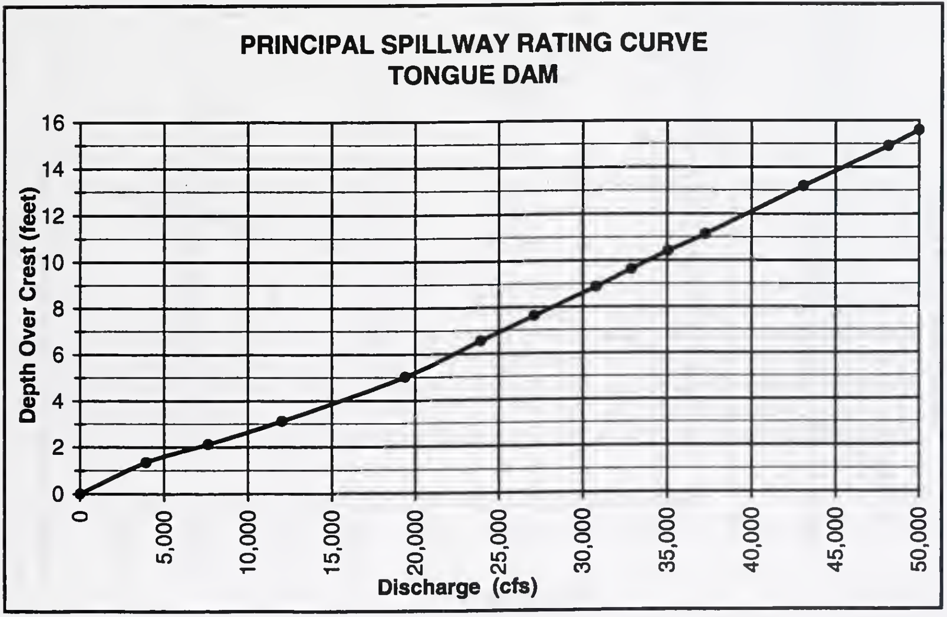
NOTE: Storage table compiled from 1995 and 1996 reservoir surveys.
Dead storage is 711 acre-feet from elevation 3360.0 to 3374.4 feet.

Spillway Crest	Elevation 3,428.4 feet	Storage 79,071 acre-feet
Emergency Spillway Crest	Elevation 3,431.5 feet	Storage 91,107 acre-feet
Dam Crest	Elevation 3,444.0 feet	

TABLE 3. PRINCIPAL SPILLWAY DISCHARGE

TONGUE DAM

Reservoir Surface Elevation (feet)	Depth Over Crest (feet)	Discharge (cfs)
3,428.40	0.00	0
3,429.75	1.35	3,941
3,430.53	2.13	7,617
3,431.52	3.12	12,036
3,433.42	5.02	19,376
3,434.96	6.56	23,930
3,436.03	7.63	27,126
3,437.27	8.87	30,786
3,438.03	9.63	32,866
3,438.81	10.41	35,059
3,439.52	11.12	37,256
3,441.59	13.19	43,088
3,443.32	14.92	48,175
3,444.00	15.60	50,000

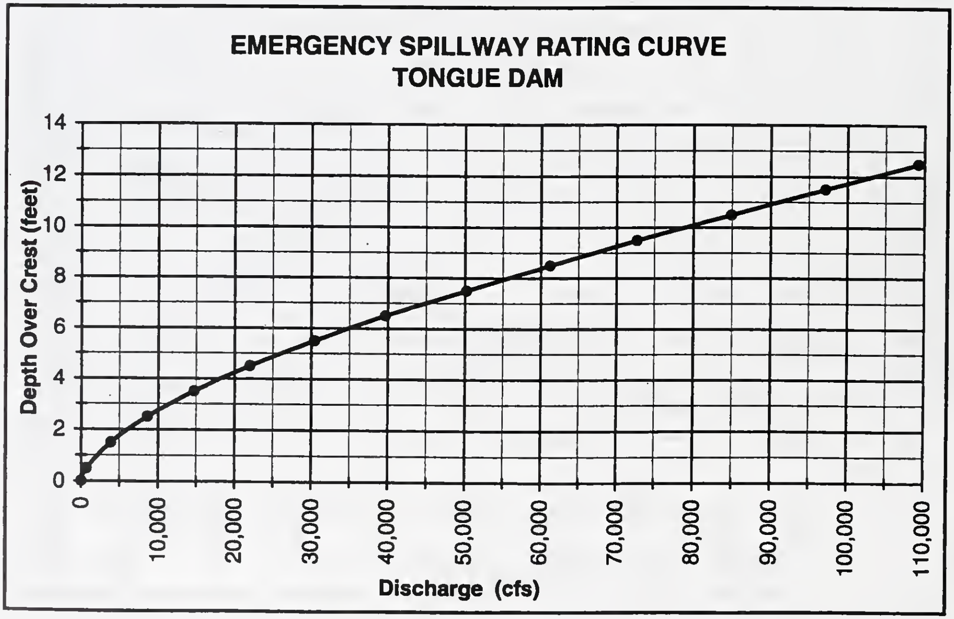


Note: Data from Final Design Report for Roller Compacted Concrete (RCC) Emergency Spillway (Phase II Construction) January, 1997.

TABLE 4. EMERGENCY SPILLWAY DISCHARGE

TONGUE DAM

Reservoir Surface Elevation (feet)	Depth Over Crest (feet)	Discharge (cfs)
3,431.5	0	0
3,432.0	0.5	700
3,433.0	1.5	3,900
3,434.0	2.5	8,600
3,435.0	3.5	14,700
3,436.0	4.5	22,000
3,437.0	5.5	30,400
3,438.0	6.5	39,700
3,439.0	7.5	50,200
3,440.0	8.5	61,200
3,441.0	9.5	72,700
3,442.0	10.5	84,900
3,443.0	11.5	97,100
3,444.0	12.5	109,200



Note: Data from Final Design Report for Roller Compacted Concrete (RCC) Emergency Spillway (Phase II Construction) January, 1997.

TABLE 5. PARSHALL FLUME RATING TABLE
9 INCH THROAT

Location: Flume Vault Building -- left and right flume

HEAD (FT)	DISCHARGE (GPM)	HEAD (FT)	DISCHARGE (GPM)	HEAD (FT)	DISCHARGE (GPM)
0.10	41	0.41	352	0.71	816.0
0.11	47	0.42	365	0.72	834.0
0.12	54	0.43	379	0.73	851.0
0.13	61	0.44	392	0.74	869.0
0.14	68	0.45	406	0.75	887.0
0.15	76	0.46	420	0.76	905.0
0.16	83	0.47	434	0.77	924.0
0.17	92	0.48	448	0.78	942.0
0.18	100	0.49	463	0.79	961.0
0.19	109	0.50	477	0.80	979.0
0.20	117	0.51	492	0.81	998.0
0.21	127	0.52	507	0.82	1017.0
0.22	136	0.53	522	0.83	1036.0
0.23	145	0.54	537	0.84	1055.0
0.24	155	0.55	552	0.85	1074.0
0.25	165	0.56	567.0	0.86	1094.0
0.26	175	0.57	583.0	0.87	1113.0
0.27	186	0.58	599.0	0.88	1133.0
0.28	196	0.59	615.0	0.89	1153.0
0.29	207	0.60	631.0	0.90	1173.0
0.30	218	0.61	647.0	0.91	1193.0
0.31	230	0.62	663.0	0.92	1213.0
0.32	241	0.63	679.0	0.93	1233.0
0.33	253	0.64	696.0	0.94	1253.0
0.34	264	0.65	713.0	0.95	1274.0
0.35	276	0.66	730.0	0.96	1294.0
0.36	288	0.67	747.0	0.97	1315.0
0.37	301	0.68	764.0	0.98	1336.0
0.38	314	0.69	781.0	0.99	1357.0
0.39	326	0.70	798.0	1.00	1378.0
0.40	339				

Note: Free flow discharge. Data provided by Planti-Fab, manufacturer.

TABLE 6. PALMER-BOWLUS FLUME RATING TABLE
12 INCH THROAT

Location: Flume Vault Building -- middle flume

HEAD (FT)	DISCHARGE (GPM)		HEAD (FT)	DISCHARGE (GPM)
0.01	------		0.36	184
0.02	------		0.37	194
0.03	------		0.38	205
0.04	4		0.39	215
0.05	6		0.40	227
0.06	8		0.41	238
0.07	11		0.42	250
0.08	14		0.43	262
0.09	17		0.44	274
0.10	20		0.45	287
0.11	23		0.46	300
0.12	27		0.47	313
0.13	31		0.48	326
0.14	35		0.49	340
0.15	39		0.50	354
0.16	43		0.51	405
0.17	48		0.52	420
0.18	53		0.53	437
0.19	58		0.54	453
0.20	63		0.55	470
0.21	69		0.56	487
0.22	75		0.57	504
0.23	81		0.58	522
0.24	87		0.59	540
0.25	93		0.60	558
0.26	100		0.61	577
0.27	107		0.62	595
0.28	115		0.63	614
0.29	122		0.64	633
0.30	130		0.65	653
0.31	138		0.66	672
0.32	147		0.67	692
0.33	156		0.68	712
0.34	165		0.69	732
0.35	174		0.70	752

Note: Free flow discharge. Data provided by Planti-Fab, manufacturer.

TABLE 7. V-NOTCH WEIR RATING TABLE

HEAD	DISCHARGE		HEAD	DISCHARGE	
(IN)	(GPM)	(CFS)	(IN)	(GPM)	(CFS)
---------	---------	---------	4.1	77.8	0.173
---------	---------	---------	4.2	82.6	0.184
---------	---------	---------	4.3	87.5	0.195
---------	---------	---------	4.4	92.6	0.206
0.5	0.4	0.001	4.5	98.0	0.218
0.6	0.7	0.001	4.6	103.4	0.230
0.7	1.0	0.002	4.7	109.1	0.243
0.8	1.4	0.003	4.8	115.0	0.256
0.9	1.8	0.004	4.9	121.0	0.270
1.0	2.4	0.005	5.0	127.2	0.283
1.1	3.0	0.007	5.1	133.6	0.298
1.2	3.7	0.008	5.2	140.2	0.312
1.3	4.5	0.010	5.3	147.0	0.328
1.4	5.4	0.012	5.4	154.0	0.343
1.5	6.4	0.014	5.5	161.2	0.359
1.6	7.5	0.017	5.6	168.5	0.375
1.7	8.8	0.020	5.7	176.1	0.392
1.8	10.1	0.022	5.8	183.8	0.410
1.9	11.5	0.026	5.9	191.8	0.427
2.0	13.1	0.029	6.0	199.9	0.445
2.1	14.8	0.033	6.1	208.3	0.464
2.2	16.6	0.037	6.2	216.9	0.483
2.3	18.5	0.041	6.3	225.6	0.503
2.4	20.6	0.046	6.4	234.6	0.523
2.5	22.8	0.051	6.5	243.8	0.543
2.6	25.1	0.056	6.6	253.2	0.564
2.7	27.6	0.061	6.7	262.9	0.586
2.8	30.2	0.067	6.8	272.7	0.608
2.9	32.9	0.073	6.9	282.8	0.630
3.0	35.8	0.080	7.0	293.0	0.653
3.1	38.9	0.087	7.1	303.5	0.676
3.2	42.1	0.094	7.2	314.2	0.700
3.3	45.4	0.101	7.3	325.2	0.725
3.4	48.9	0.109	7.4	336.3	0.749
3.5	52.5	0.117	7.5	347.7	0.775
3.6	56.3	0.126	7.6	359.3	0.801
3.7	60.3	0.134	7.7	371.2	0.827
3.8	64.4	0.144	7.8	383.2	0.854
3.9	68.7	0.153	7.9	395.5	0.881
4.0	73.1	0.163	8.0	408.1	0.909

$Q = (2.49\ (H/12)^{2.48})(448.83)$
Q in gpm
H in inches

APPENDIX C

EMERGENCY GATE MAINTENANCE PROCEDURES

Emergency Gate Maintenance Procedures

The maintenance mode of operation is for the **emergency gates only** for both outlets. The procedure below relates to removal of the gate leaf from the gate shaft for maintenance activities.

Removal of the emergency gate should only be done with SWPB staff onsite.

The following terms are used in this procedure.

Maintenance Stem. Maintenance stem consists of a short length of stem (approximately 1 ft. long) with a male clevis on one end and a female clevis on the other end. The pin-to-pin distance of the maintenance stem is approximately 16 in. long.

Gate Stem. Each gate is equipment with 8 stem sections, approximately 8 ft. long plus one additional stem somewhat shorter that connects to the gate leaf itself. Each stem is equipped with a male clevis on one end and a female clevis on the other end.

Maintenance Clevis. The maintenance clevis is the clevis used to connect the hydraulic cylinder piston rod to the gate mounted lifting lug. This clevis is wider than the regular piston mounted clevis to accommodate the larger width of the gate lifting lug.

1. Removal of Gate For Maintenance

   Initial Position of Gates: ***Downstream operating gate full closed. Emergency gate full open under balanced water pressure.***

   (a) In the main gate control panel, turn "Maint. Switch" to "MAINT." This places the control of the emergency gate to the push button control box on the wall near the emergency gate in the maintenance pit.

   The raise and lower buttons are "momentary contact switches" so that when they are pushed they provide power for only as long as they are pushed down. When the button is held down for 10 seconds or longer, then the pump will operate continuously until the stop button is pushed or the cylinder reaches the full open or closed position.

(b) Engage dogging device under clevis of second gate stem and lower gate until gate weight load is transferred from the hydraulic cylinder to the dogging device.

(c) Disconnect first gate stem from second gate stem by removing cotter pin and main pin from clevis.

(d) Lower hydraulic cylinder until top gate stem clevis is within reach and remove first gate stem.

(e) Install **maintenance stem** to hydraulic cylinder clevis.

(f) Lower hydraulic cylinder and connect maintenance stem to dogged stem.

(g) Begin raising gate, retract dogging device, and continue raising gate until cylinder is at full raised position.

(h) Engage dogging device under clevis of next gate stem and transfer load from cylinder to the dogging device.

(i) Disconnect upper gate stem from lower gate stem by removing cotter pin and main pin from clevis.

(j) Lower hydraulic cylinder until top clevis of gate stem is within reach and disconnect and remove gate stem from maintenance stem.

(k) Lower hydraulic cylinder and connect maintenance stem to dogged stem.

(l) Repeat Steps (g) through (k) until second to last stem is removed.

(m) Lower hydraulic cylinder and connect maintenance stem to last dogged gate stem.

(n) Raise hydraulic cylinder until flange of gate leaf's top girder is above dogging device and engage dogging device underneath top girder flange.

(o) Lower gate until gate weight load is transferred from the hydraulic cylinder to the dogging device at the top girder. Make sure the front tabs of the dogging arm engage the underside of girder flange.

(p) Remove last gate stem.

(q) Remove maintenance stem.

(r) Remove piston rod mounted clevis by loosening set screw and unthreading the clevis from the stem.

(s) Install **maintenance clevis** to hydraulic cylinder piston rod.

> Note: Tighten set screw in clevis and make sure lead shot is between set screw and hydraulic stem. Otherwise, threads get marred and removal/installation of clevis is difficult.

(t) Lower hydraulic cylinder and connect maintenance clevis to gate leaf.

(u) Raise gate up until gate mounted maintenance lugs line up with monorail trolleys (auxiliary emergency gates) or maintenance hanger (primary emergency gate). Connect same with provided pins/shackles. Remove pin from maintenance clevis to detach gate from hydraulic cylinder.
(v) *(Auxiliary Gate Only).* Gate can be manually moved in downstream direction via maintenance trolleys to limits of stops on monorail beams.

2. Reinstallation of Gate

Initial Position of Gates: ***Downstream operating gate closed. Emergency gate hanging in maintenance position on hanger/ trolleys.***

(a) With maintenance clevis installed on hydraulic cylinder piston rod, attach clevis to gate mounted lifting lug.
(b) Operate hydraulic cylinder to transfer load from maintenance hanger/trolleys to the hydraulic cylinder.
(c) Remove pins to disengage gate mounted maintenance lugs from hanger/trolleys.
(d) Lower gate leaf and engage dogging device under topmost girder flange of gate leaf. Lower until gate leaf weight is taken by the dogging device.
(e) Disconnect gate leaf from maintenance clevis and remove maintenance clevis.
(f) Install regular piston rod clevis.

Note: Tighten set screw in clevis and make sure lead shot is between set screw and hydraulic stem. Otherwise, threads get marred and removal/installation of clevis is difficult.

(g) Attach maintenance stem to clevis.
(h) Attach bottommost gate stem to maintenance stem. Raise hydraulic cylinder and connect stem to gate. Transfer load from dogging device to hydraulic cylinder.
(i) Disengage dogging device from gate and lower gate via hydraulic cylinder.
(j) Engage dogging device under top clevis of gate stem and transfer load from cylinder to the dogging device.
(k) Disconnect bottom gate mounted stem from maintenance stem/hydraulic cylinder.
(l) Attach next loose gate stem to maintenance stem and raise hydraulic cylinder.
(m) Connect loose gate stem to dogged stem. Transfer load back to stems by operating hydraulic cylinder.

(n) Disengage dogging device and lower gate via hydraulic cylinder.

(o) Repeat Steps (j) through (n) until all but last stem has been installed.

During lowering of the gate, make sure gate stem rods remain under tension. Also, make sure gate guides engage guide rails.

(p) Engage dogging device under top clevis of gate stem and transfer load from cylinder to the dogging device.

(q) Remove maintenance stem. Raise hydraulic cylinder.

(r) Insert last gate stem.

(s) Lower gate to full closed position.

(t) Switch "Maint. Switch" back to "Normal" mode to transfer control of hydraulic cylinder from maintenance pushbutton station to main control panel.

APPENDIX D

INSPECTION REPORT FORM

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
DAM SAFETY INSPECTION REPORT

NAME OF DAM
DATE INSPECTED

INVENTORY NO. ____________
HAZARD CATEGORY ____________
TYPE OF DAM ____________
YEAR BUILT ____________

OWNER ____________
OPERATOR ____________
STREAM ____________
DRAINAGE AREA ____________

Reservoir Storage Status

	Water Surface Elevation (feet)	Storage (acre-feet)
At time of inspection		
At spillway crest		
At min. dam crest elevation		

ITEM	**YES**	**NO**	**REMARKS**

1. EMBANKMENT

A. Crest -- Height= Length= Width=

(1) Any visual settlements?			
(2) Any misalignments?			
(3) Any cracking?			
(4) Any traffic damage?			
(5) Other?			

ITEM	YES	NO	REMARKS

1. **EMBANKMENT** (continued)

B. Upstream Face – Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Is riprap protection adequate?			
(5) Any stone deterioration?			
(6) Any visual settlement, slumps, sloughing, depressions or bulges?			
(7) Adequate grass cover?			
(8) Debris on the dam face?			
(9) Other?			

C. Downstream Face--Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Any visual settlement, slumps, sloughing, depressions or bulges?			
(5) Is the toe drain dry?			
(6) Are the relief wells flowing?			
(7) Any boils at the toe?			
(8) Any seepage areas?			
(9) Any traffic or animal damage?			
(10) Any burrowing animals?			
(11) Adequate grass cover?			
(12) Other?			

D. Amount and Type of Vegetation on the Dam

ITEM	YES	NO	REMARKS

2. ABUTMENT CONTACTS

A) Any erosion?			
B) Any visual differential movement?			
C) Any cracks?			
D) Any seepage present?			
E) Other?			

3. OUTLET WORKS

A. Intake Structure -- Size=

(1) Any settlement?			
(2) Any tilting?			
(3) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(4) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(5) Metal appurtenances:			
a. Any corrosion present?			
b. Any breakage present?			
(6) Trash rack?			
a. Condition?			
b. Anchor system secure?			
(7) Other?			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

B. Conduit -- Type = Size =

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(3) Is the conduit metal?			
a. Any corrosion present?			
b. Protective coatings adequate?			
(4) Is the conduit misaligned?			
(5) Any calcium deposits?			
(6) Other?			

C. Gates and Tower

(1) Gates:			
a. Size: Operating: b. Type: Operating:	Emergency: Emergency:		
(2) Controls operational?			
(3) Controls lubricated?			
(4) Operational problems?			
(5) Leakage around gates?			
(6) Condition of gate seals?			
(7) Any cavitation damage? If so, describe?			
(8) Describe air vent-size and condition.			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

C. Gates and Tower (continued)

(9) Is there a jet pump?			
a. Is it operational?			
b. Leakage?			
(10) Is the tower dry? ____ wet?			
(11) Any seepage in the tower?			
(12) Condition of the tower?			
(13) Any safety problems?			
(14) Ladder in good condition?			
(15) Condition of the gatehouse?			
(16) Emergency plan completed for the dam?			
a. Posted in the gatehouse?			
(17) Other?			

D. Stilling Basin

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(3) Do energy dissipaters show:			
a. Signs of deterioration?			
b. Are they covered with debris?			
(4) Other?			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

E. Downstream Channel

(1) Is the channel:			
a. Eroding or backcutting?			
b. Sloughing?			
c. Obstructed?			
(2) Is released water:			
a. Undercutting the outlet?			
b. Eroding the embankment?			
(3) Other?			

4. SPILLWAY

A. Description

(1) Location?			
(2) Type of Spillway?			
(3) Size of Spillway?			
(4) Spillway lining?			
(5) Is there a weir?			
(6) Is the spillway in good condition?			
(7) Any drains?			
a. Describe the condition of drains.			

B. Does spillway show:

(1) Any cracking concrete?			
(2) Any spalling concrete?			
(3) Any exposed reinforcement in the concrete?			
(4) Any erosion?			

ITEM	YES	NO	REMARKS

4. SPILLWAY (continued)

4. B. Does spillway show: (continued)

(5) Any slope sloughing?			
(6) Any obstructions?			
(7) Displacement or offset joints?			
(8) Loss of joint material?			
(9) Leakage at the joints?			
(10) Other?			

C. Do the energy dissipaters show:

(1) Signs of deterioration?			
(2) Any cracking?			
(3) Any spalling?			
(4) Any exposed reinforcement?			
(5) Are they covered with debris?			
(6) Other?			

D. Has release water:

(1) Eroded the embankment?			
(2) Undercut the outlet?			
(3) Eroded the downstream channel?			
(4) Other?			

E. Emergency Spillway

(1) Is there an emergency spillway?			(If YES, describe)

ITEM	YES	NO	REMARKS

5. RESERVOIR CONTROL

A) Recent upstream development?			
B) Recent downstream development?			
C) Slides in reservoir area?			
D) Change in reservoir operation?			
E) Large impoundment upstream?			
F) Any debris in the reservoir?			
G) Other?			

6. INSTRUMENTATION

A) List type(s) of instrumentation:			
B) In good condition?			
C) Read periodically?			
D) Is data available?			
E) Include all data gathered since last report.			

7. DOWNSTREAM CONDITION

A. Downstream Land Use.

This dam was inspected by:

Additional comments and recommendations.

APPENDIX E

O&M MANUAL DISTRIBUTION LIST

O&M MANUAL DISTRIBUTION LIST

TONGUE RIVER DAM

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Keith Kerbel	
Dave Adair	
4. Dam Safety	1
5. Primary and Auxiliary Gatehouses	2
6. Water Users	4
Art Hayes -- President	
Les Hirsch -- Vice President	
Pat Helm -- Secretary/Treasurer	
Mark Van Haele -- Dam Operator	
8. Miscellaneous	2
Ms. Margarie Eagleman, Superintendent, BIA, Lame Deer	
Ms. Geri Small, Tribal Council President, Lame Deer	
7. State Library -- Attn: Roberta Gebhart	4
8. Extras	2
TOTAL	24

APPENDIX F

MONITORING WELL LOGS

TABLE 8. TONGUE RIVER DAM MONITORING WELLS

New Name	Old Name	Year Drilled	Type		Total Depth (ft)	Standpipe Wells		Vibrating Wires	
			(sp)	(vw)		Depth (ft)	TOP Elev (ft)	Depth (ft)	Reference Elev (ft)
1A	DH-1Z (A)	1967	sp		151.4	90	3430.70		
1B	DH-1Z (B)	1967	sp		151.4	43.2	3430.70		
2	DH-2	1967	sp		144.3	71.5	3441.80		
101	101	1982	sp		180.6	84.6	3484.70		
102	102	1982	sp		94.3	70	3433.00		
120A	DH-120Z(A)	1984	sp		273	226	3470.00		
120B	DH-120Z(B)	1984	sp		273	114	3470.00		
209A	DH-9(A)	1995	sp	vw	100	100	3443.10	98.1	3443.10
209B	DH-9(B)	1995	sp	vw	70	70	3443.20	48.9	3443.20
214	DH-14	1995	sp		47	47	3384.00		
250	MW-A3	1995/96	sp		?	?	3363.00		
251	DW	1995/96	sp		?	?	3362.30		
310	H-10	1998	sp	vw	78.5	77.5	3450.90	80.3	3450.90
401	P-WD2	1999	sp	vw	18.8	18.0	3444.10	19.01	3444.10
402	P-WD1	1999		vw	18.8			19.55	3422.97
403	P-SA2	1999		vw	30.5			28.98	3417.09
404	P-SA1	1999		vw	29.3			28.5	3416.82
405	P-US2	1999		vw	61.9			59.9	3438.49
406A	P-US1(A)	1999		vw	68.5			66.5	3436.08
406B	P-US1(B)	1999		vw	68.5			36	3436.08
407	AH-3	1999	sp	vw	75.5	71.0	3443.30	74.3	3443.30
408	AH-5	1999	sp	vw	81	80.0	3440.80	78	3440.80
409	P-CL1	1999	sp	vw	75	72.6	3442.40	72.38	3442.40
410A	P-CC1(A)	1999	sp		70.6	70.1	3427.81		
410B	P-CC1(B)	1999	sp		70.6	28.4	3427.81		
411A	P-CC2(A)	1999	sp		84.1	68.9	3428.12		
411B	P-CC2(B)	1999	sp		84.1	83.9	3428.12		
412A	P-CR2(A)	1999	sp	vw	132	85.0	3443.20	84.5	3443.20
412B	P-CR2(B)	1999	sp	vw	132	130.0	3443.20	130	3443.20
412C	P-CR2(C)	1999	sp	vw	98.7	98.2	3443.00	99.3	3443.00
413	P-CR1	1999	sp	vw	49.2	46.0	3444.70	45.7	3444.70
414	P-DR2	1999	sp		44.5	43.1	3365.32		
415	P-DR1	1999	sp		20.5	18.4	3365.88		

Standpipe Well Depth = depth below top of pipe (TOP) elevation
Vibrating Wire Depth = depth below reference elevation

Number of drill holes = 25
Number of monitoring wells = 33

Number of monitoring wells (standpipes only)	16
Number of monitoring wells (vibrating wire piezometers only)	6
Number of monitoring wells (vibrating wire and standpipe)	11
	33

COORD. N. 23712
E. 87960

BECHTEL CORPORATION

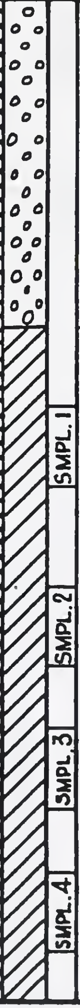
GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4
HOLE NO. 1

PROJECT 6694 TONGUE RIVER
ANGLE FROM HORIZ. VERTICAL
BEARING --
LOCATION UPSTREAM EDGE OF DAM CREST; EXISTING DAM
BEGUN 7-10-67
COMPLETED 7-17-67
OVERBURDEN 133.5' - FILL
DEPTH DRILLED INTO ROCK 17.9'
TOTAL DEPTH OF HOLE 151.4'
ELEV. WATER TABLE P1-3352'
NO. CORE BOXES 1
NO. SAMPLES TAKEN 21
CORE RECOVERY (%) 75
FEET 11.2
MODEL & MAKE OF DRILL B52 MOBILE DRILL
GROUND ELEV. 3442
HOLE LOGGED BY THIEL & BOCK
DRILLER MEL COUTURE

NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.	% CORE RECOVERY	PRESSURE TESTS LOSS IN G.P.M.	PRESSURE P.S.I.	TIME IN MIN.	ELEVATION	DEPTH	CLASSIFICATION AND PHYSICAL CONDITION
LOST ALL CIRCULATION AND FLUID; SET 5" CASING TO 20 FEET.					3442	0	UPSTREAM SHELL; BAKED SANDSTONE AND SHALE, CLINKER AND SCORIA, EXTREMELY PERMEABLE.
					3437	5	
					3432	10	
							SANDY CLAY: GRAY, MOIST, FIRM AND STIFF. LOW TO MEDIUM PLASTICITY. (CL)
					3427	15	
					3422	20	
					3417	25	
					3412	30	
					3407	35	

LOG / SAMPLE RUN



Hole Size 4-5/8"

HOLE NO. 1
SITE DAM CREST
EXIST DAM

SHEET 2 OF 4

PROJECT 6694 TONGUE RIVER

HOLE NO. 1

NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.,	% CORE RECOVERY	PRESSURE TESTS LOSS IN G.P.M.	PRESSURE TESTS PRESSURE P.S.I.	PRESSURE TESTS TIME IN MIN.	ELEVATION	DEPTH	LOG	CLASSIFICATION AND PHYSICAL CONDITION
					3407	35	SMPL.5	
Bottom of Piezometer 2 ▽ Sand Backfill 45' to 35.8' Grout 35.8'-34.0'					3402	40	SMPL.6	
					3397	45	SMPL.7	Some gravel in sample
					3392	50	SMPL.8	
					3387	55	SMPL.9	
					3382	60	SMPL.10	
					3377	65	SMPL.11	
▽					3372	70	SMPL.12	
					3367	75		Scattered roots

Hole Size 4-5/8"

HOLE NO. 1

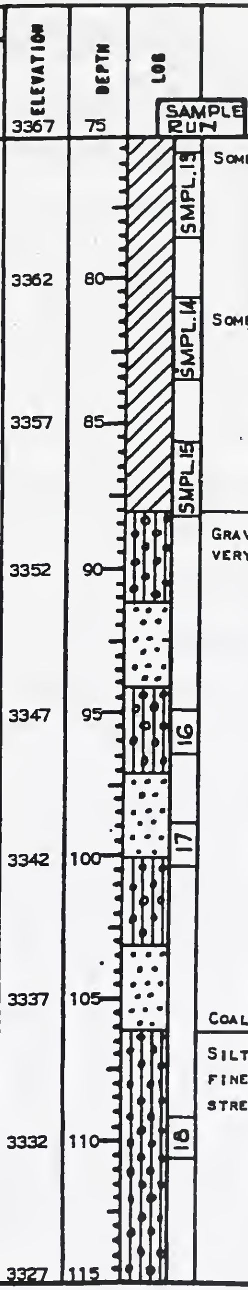
SITE Dam Crest
Exist. Dam

PROJECT 6694 TONGUE RIVER

SHEET 3 OF 4

HOLE NO. 1

NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.,	% CORE RECOVERY	PRESSURE TESTS LOSS IN G.P.M.	PRESSURE TESTS PRESSURE P.S.I.	PRESSURE TESTS TIME IN MIN.
BOTTOM OF PIEZOMETER 1. SAND BACKFILL: 85'-151.4'. IMPERVIOUS BACKFILL TO 58.3'. GROUT TO 57.3' PARTIAL LOSS OF DRILLING FLUID				



CLASSIFICATION AND PHYSICAL CONDITION

SOME GRAVEL IN SAMPLE

SOME GRAVEL IN SAMPLE

GRAVELLY SILTY SAND: DARK GRAY, VERY DENSE, WET (SP-SM)

COAL FRAGMENTS

SILTY SAND: DARK GRAY TO BLACK, FINE GRAINED WITH THIN LAYERS OF STREAM DEPOSITED COAL DEBRIS. (SM)

Hole Size 4-5/8"

HOLE NO. 1

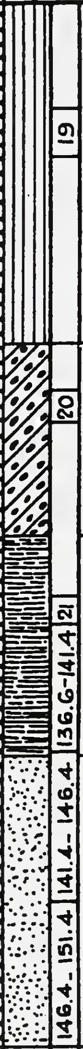
SITE DAM CREST

EXIST. DAM

SHEET 4 OF 4

PROJECT 6694 TONGUE RIVER

HOLE NO. 1



NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.,	% CORE RECOVERY	PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE TESTS: PRESSURE P.S.I.	PRESSURE TESTS: TIME IN MIN.	ELEVATION	DEPTH	LOG	CLASSIFICATION AND PHYSICAL CONDITION
					3327	115		
					3322	120	19	WET, DENSE
					3317	125		
					3312	130	20	CLAYEY SANDY GRAVEL: DARK GRAY, VERY DENSE, MOIST (GC)
					3307	135	21 136.6-141.4	SILTSTONE: LIGHT GRAY, TRACE OF VERY FINE SAND, VERY FIRM, GRADES SANDIER
					3302	140		
CORE LENGTHS: 1.7-3.0'	75	25.6	65	5	3297	145	141.4-146.4 146.4-151.4	SANDSTONE: LIGHT GRAY, FINE GRAINED, MODERATELY CEMENTED, LIGHT GRAY, CARBONACEOUS LAMINATIONS
					3292	150		
					3290.6			T.D. 151.4'

Hole Size 4-5/8"

HOLE NO. 1

SITE DAM CREST

GEO-TESTING, INC.
EARTH MATERIALS LABORATORY

Sheet ____ of ____

VISUAL CLASSIFICATION

Project: Tongue River – Bechtel Job 6694-2

Date:

Hole No.	Sample No.	Depth	Classification
1	1	14.2'- 17.0'	Top & Bottom - Brown, Moist, Stiff, Plastic Clay (CL) With Occasional Red Shale Chips
	2	20.5'- 23.3'	Brown, Firm, Moist, Plastic Clay (CL) With Occasional Red Shale Chips
	3	25.5'	Top - Brown, Firm, Moist, Plastic Sandy Clay (CL) With Occasional Gravel Up To 1½"
		28.3'	Bottom - Brown, Firm, Moist, Plastic Clay (CL) With Chips Of Red Shale
	4	30.5'- 33.0'	Brown, Stiff, Moist, Plastic Sandy Clay (CL) With Some +4 -3/8 Gravel
	5	35.5'- 38.3'	Brown, Stiff, Moist, Plastic Clay (CL) With Occasional Gravel To ½"
	6	40.5'- 43.0'	Brown, Stiff, Moist, Plastic Clay (CL) With Occasional Gravel +4
	7	47.6'- 48.3'	Brown, Stiff, Moist, Plastic Sandy Clay (CL) With Occasional Gravel Sizes To ¾" And Local Pockets Of Coarse Silty Sand (+#4 -#4)
	8	51.3'- 53.3'	Brown, Stiff, Moist, Plastic Sandy Clay (CL) With Occasional +4 -¾" Gravel
	9	55.5'- 58.3'	Brown, Stiff, Moist Plastic Sandy Clay (CL) With Occasional ½" Gravel
	10	60.5'- 63.3'	Brown, Stiff, Moist, Plastic Clay (CL) With Lenses Of Silty Sand
	11	65.5'- 68.3'	Brown, Firm, Moist, Plastic Sandy Clay (CL)
	12	70.5'- 73.3'	Brownish, Gray, Stiff, Moist, Plastic Sandy Clay (CL)
	13	75.5'- 78.3'	Brown, Stiff, Moist, Plastic Sandy Clay (CL) With Lenses Of Fine Sand
	14	80.5'- 83.3'	Brown, Stiff, Moist, Plastic Sandy Gravelly Clay (CL) With Lenses Of Fine Sand And Occasional Chips Of Red Shale
	15	85.5'- 88.0'	Gray, Firm, Moist, Plastic Sandy Silty Clay (CL)

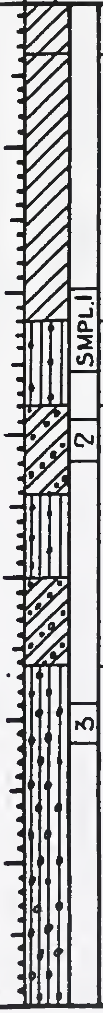
COORD. N. 23759
E. 87977

BECHTEL CORPORATION
GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4
HOLE NO. 2

PROJECT 6694 TONGUE RIVER
ANGLE FROM HORIZ. VERTICAL
BEARING --
LOCATION DOWNSTREAM EDGE OF DAM CREST; EXISTING DAM
BEGUN 19 JULY 67
COMPLETED 24 JULY 6
OVERBURDEN 133.4'
DEPTH DRILLED INTO ROCK 10.9'
TOTAL DEPTH OF HOLE 144.3'
ELEV. WATER TABLE P3-DRY AT 70.6'
NO. CORE BOXES 1
NO. SAMPLES TAKEN 12
CORE RECOVERY (%) 83
FEET 7.5'
MODEL & MAKE OF DRILL B52 MOBILE DRILL
GROUND ELEV. 3442'
HOLE LOGGED BY THIEL & BOCK
DRILLER MEL COUTURE

NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.	% CORE RECOVERY	PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE TESTS: PRESSURE P.S.I.	PRESSURE TESTS: TIME IN MIN.	ELEVATION	DEPTH	LOG	SAMPLE RUN	CLASSIFICATION AND PHYSICAL CONDITION
					3442	0			SANDY GRAVELLY CLAY: FIRM, DRY, REDDISH BROWN (CL)
									SANDY CLAY: GRAY, MEDIUM STIFF (CL)
					3437	5			
					3432	10		SMPL. 1	CLAYEY SANDY GRAVEL: REDDISH BROWN, MOIST, VERY DENSE (GM-GC)
					3427	15		2	
					3422	20			
					3417	25		3	GRAVELLY SILTY SAND: MOIST, DENSE (SM)
					3412	30			
					3407	35			



Hole Size 4-5/8"

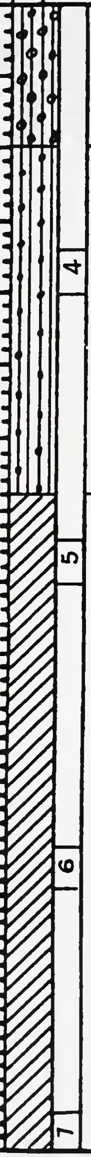
HOLE NO. 2
SITE DAM CREST
EXIST. DAM

SHEET 2 OF 4

PROJECT 6694 TONGUE RIVER

HOLE NO. 2

NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.,	% CORE RECOVERY	PRESSURE TESTS LOSS IN G.P.M.	PRESSURE TESTS PRESSURE P.S.I.	PRESSURE TESTS TIME IN MIN.	ELEVATION	DEPTH	LOG / SAMPLE RUN	CLASSIFICATION AND PHYSICAL CONDITION
					3407	35		
					3402	40		SANDY SILTY GRAVEL: REDDISH BROWN MOIST, VERY DENSE (GM)
							4	
					3397	45		
					3392	50		
								SANDY CLAY: BROWN, MOIST, VERY STIFF TO HARD.
							5	
					3387	55		
					3382	60		
							6	
					3377	65		
					3372	70		
BOTTOM OF PIEZOMETER 3 SAND BACKFILL TO 39.0 GROUT TO 36.4'								
							7	
					3367	75		



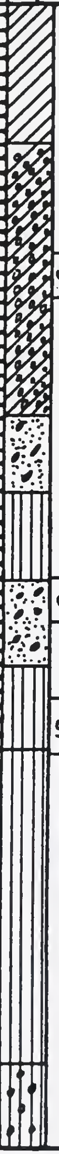
Hole Size 4-5/8"

HOLE NO. 2
SITE DAM CREST
EXIST. DAM

SHEET 3 OF 4

PROJECT 6694 TONGUE RIVER

HOLE NO. 2



NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.,	% CORE RECOVERY	PRESSURE TESTS LOSS IN G.P.M.	PRESSURE TESTS PRESSURE P.S.I.	PRESSURE TESTS TIME IN MIN.	ELEVATION	DEPTH	SAMPLE RUN	CLASSIFICATION AND PHYSICAL CONDITION
					3367	75		
					3362	80		CLAYEY SAND: BROWN, MOIST, HARD (SC)
					3357	85	8	
LOSING SOME WATER AT 92'					3352	90		ORIGINAL GROUND: SANDY SILTY GRAVEL, BROWN, MOIST, VERY DENSE, GRAVELS ARE ANGULAR AND BROKEN (GP-GM)
					3347	95	9	
					3342	100	10	SANDY SILT: BROWN, MOIST, DENSE, WITH SMALL PIECES OF COAL (ML)
					3337	105		
					3332	110		SILTY SAND: GRAY, MOIST, VERY DENSE, GRAVEL TO 1/2" (SP-SM)
					3327	115		

Hole Size 4-5/8"

HOLE NO. 2

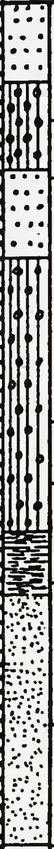
SITE DAM CREST
EXIST. DAM

SHEET 4 OF 4

PROJECT 6694 TONGUE RIVER

HOLE NO. 2

NOTES ON WATER TABLE LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.,	% CORE RECOVERY	PRESSURE TESTS: LOSS IN G.P.M.	PRESSURE TESTS: PRESSURE P.S.I.	PRESSURE TESTS: TIME IN MIN.	ELEVATION	DEPTH	SAMPLE RUN	CLASSIFICATION AND PHYSICAL CONDITION
					3327	115		
					3322	120	11	
					3317	125		GRAVELLY SILTY SAND: MOTTLED, DAMP, VERY DENSE, GRAVEL TO 3/4"
SET NX CASING TO 133.9'					3312	130	12	
					3307	135		SILTSTONE: GRAY; LAMINATED TO MASSIVE; FIRM
CORE LENGTHS: 0.1-0.4'	83				3302	140	135.2-140.2' 140.2'-144.3	SANDSTONE: LIGHT GRAY; FINE GRAINED; SILTY; MODERATELY CEMENTED; CARBONACEOUS LAMINATIONS
					3297.7			T.D. 144.3'



Hole Size 4-5/8"

HOLE NO. 2

SITE DAM CREST
EXIST. DAM

GEO-TESTING, INC.
EARTH MATERIALS LABORATORY

Sheet ____ of ____

VISUAL CLASSIFICATION

Project: TONGUE RIVER - BECHTEL JOB 6694-2

Date:

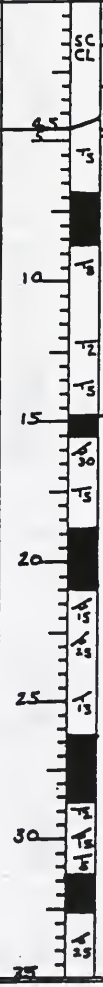
Hole No.	Sample No.	Depth	Classification
2	1	10.0'– 11.8'	TOP - BROWN, STIFF, MOIST, PLASTIC, SANDY CLAY (CL) BOTTOM - BROWN, FIRM, SANDY CLAYEY GRAVEL (GC-GM) SIZE UP TO +1"

R.C.HARLAN AND ASSOCIATES

SHEET 1 OF 5

DRILL LOG	PROJECT TONGUE RIVER — EXISTING DAM	JOB NO. 169.9	HOLE NO. DH-101E
SITE/LOCATION LEFT ABUTMENT	BEGUN 8/31/82 / COMPLETED 9/10/82	HOLE SIZE 9" / 3"	ANGLE FROM HORIZ. & BEARING VERTICAL
COORDINATES N. 25,883 E. 85,009	GROUND WATER DEPTH / EL. NOT ESTABLISHED	GROUND EL. 3484.7'	TOP OF ROCK DEPTH / EL. 4.5'/ 3480.2'
DRILLING CONTRACTOR NORTHERN TESTING LABORATORIES	CORE REC. LENGTH / % $\frac{155.7'}{175.9'}$ = 89% / SAMPLES 4	CORE BOXES 15	BOTTOM OF HOLE DEPTH / EL. 180.6'/ 3304.1'
DRILL MAKE AND MODEL MOBILE B-50	LOGGED BY: CHARLES I. TRANTHAM		

REMARKS: WATER LEVELS, WATER RETURN, WATER TESTS, DRILLING FLUID, CASING DEPTH	WATER TEST: LOSS GPM	WATER TEST: PRESSURE PSI	BLOWS / ft. ROD	ADVANCE / RECOVERY	ELEVATION	DEPTH	GRAPHIC LOG	BOX/SAMPLE NO.	MATERIAL CALSSIFICATION / PHYSICAL DESCRIPTION



DRILLER-MORRIS ORMOND
HELPER-CLINT NELSON

Hole located in gully on left abutment in area of proposed spillway.

4.5-4.7' Hole advanced using 3"OD Modified Calif split Barrel Sampler 50/3" & bouncing on rock.

4.7' Bottom of 9"⌀ OD hollow stem auger with 3½" ID center opening.

4.7' Begin NX coring. Drill to 12.5; hole chunking reamed NW casing to 12.5 made run w/ 5' NQ wireline to 15.5. Contract calls for NX coring. Crew reamed NX casing to 15' & drilled w/ 5' NQ barrel w/ split innertube, to get better core recovery.

WATER TEST NO. 1
4.7-12.5 FALLING HEAD TEST- Hole size-3"⌀, casing stickup 1.5'.

Time	Drop below ground
0 sec	0.1'
30 "	0.3'
1 min 0 "	0.5'
2 " 0 "	0.9'
3 " 0 "	1.2'
4 " 0 "	1.5'

17' Driller reports sticky (clay?) area, also at 22 & 22.5'.

WATER TEST NO2
17.3-35.1' PACKER TEST-
Take 17.1gpm @ 5psi
" 22.6 " @ 10 "
" 21.0 " @ 5 "
pressure gage 1.3 above ground. Last reading for 2½ minutes - out of water.

26.2 End shift @ 5:30 on 8/31/82 - filled hole to surface w/ water; begin shift @ 8:00 on 9/1/82, water level @ 23.9', NX csg @ 15'.

SAMPLE ABBREV.—

J- JAR L- LINER

NOTE: DARK AREAS IN GRAPHIC LOG COLUMN INDICATE NO MATERIAL RECOVERY.

WATER TEST	LOSS GPM	PRESSURE PSI	BLOWS	ADVANCE / RECOVERY	ELEVATION	DEPTH	BOX/SAMPLE NO.
SPLIT BBL 2½"OD			7 11 14	18"/18"			1J
SPLIT BBL 2½"OD			22 30 26	18"/18"			2J
STD PEN 2"OD			22 36 33	18"/18"	3480.2	4.5	3J
			0	RUN 1 D-2.1' C-2.1' CL-2.1' 6.8		4.7	BOX 1 PLASTIC
			0	RUN 2 D-1.5 C-0 CL-0 8.3			
			0	RUN 3 D-4.2' C-3.8' CL-0.4' %-90 LP-0.3' 12.5'			
			0	RUN 4 D-3.0' C-2.3' CL-0.7' %-77 LP-0.1		14.7	
		0.5	0	RUN 5 D-5.7' C-2.6' CL-2.1' %-63 LP-0.5'			BOX 2 CORE
	17.1 22.6 21.0	5 10 5		21.2'			
			8	RUN 6 D-5.0' C-5.0' CL-0 %-100 LP-0.4' 26.2'			
			8	RUN 7 D-5.1' C-2.6' CL-2.5' %-51 LP-0.4' 31.3'			
			13	RUN 8 D-3.8' C-2.5' CL-1.3' %-66 LP-0.5' 35.1'	3449.7	35	

0-4.5' QUATERNARY COLLUVIUM
BROWN CLAYEY GRAVELLY SAND- Loose, dry; approx 50% sand, 30% gravel, 20% clay. Scattered platy hard sandstone fragments avg 1" thick 2.0' medium dense.

4.5-180.6' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER-

4.5-39' SILTSTONE-SANDSTONE INTERBEDDED - Fine-grained, brown & gray brown, decomposed & intensely weathered, very soft & med hard, very intensely fractured.

4.7-5.5' SANDSTONE - Med-grained, brown gray, med hard, v. intensely fractured. HCl-strong.

5.5-12.5' SILTSTONE - lt brown & brown, decomposed, very soft, v. intensely fractured. HCl- weak & med.

12.5-22.8' SILTSTONE - Light brown, decomposed, intensely weathered, soft, intensely fractured - 0.1 to 0.3' spacing w/ 90% breaks along bedding, 10% along joints. HCl- weak. Drills to avg 0.1, max 0.3' cores

18-19' Med hard, med weath, brown fine-grained sandstone. HCl-strong

23.8-24.6' SANDSTONE - Fine-grained, gray, lt weathered, hard, intensely fractured avg 0.2' - 20% bedding & 80% joints. HCl - strong

24.6-28.7' SILTSTONE - Brown & red brown, intensely weathered, soft, v. intensely fractured.

25.8-26' Med hard, brown, fine-grained sandstone. HCl-strong.

28.7-30.0' SANDSTONE - Fine & med-grained, gray, med weathered, soft, intensely fractured. HCl-none, friable.

30.0-39.0' SILTSTONE - Brown, red & dark gray, intensely weathered, soft & med hard, intensely fractured. HCl- med & strong. Drills to avg 0.1, max 0.5' cores controlled 90% by bedding & 10% joints.

31.4-31.6' Soft clay? driller rpts no resistance but not void.

HOLE NO. DH-101E

R.C. HARLAN AND ASSOCIATES

SHEET 2 OF 5

DRILL LOG	PROJECT TONGUE RIVER — EXISTING DAM	JOB NO. 169.9	HOLE NO. DH-101Z

REMARKS — WATER LEVELS, WATER RETURN, WATER TESTS, DRILLING FLUID, CASING DEPTH

NOTE: ALL BEDDING & JOINT INCLINATIONS ARE WITH CORE AXIS.

WATER RETURN

4.7 - 8.5'	100% lt brown	
8.5 - 10.0	NONE	
10.0 - 12.5	80% yell-brn	
12.5 - 22.0	100% brown	
@ 22 & 22.5'	100% red-brown	
23.0 - 23.5	100% whitish	
23.5 - 30.3	"	brown

30.3 - 44.0 NONE — water standing in hole @ approx. Got water return on reaming HX casing to 44'.

Begin Run 10, 2.5' cuttings/slough
" Run 11, 4' cuttings/slough
" Run 12, 5' " "
Ream HX Csg 15 to 20'
Begin Run 13 5' cuttings/slough
" Run 14 ½' " "
" Run 15 1' " "
" Run 16 1' " "
" Run 17 1.3' " "
Ream HX Csg to 22'
Begin Run 20 3' cuttings/slough
Run water test No 3 & stuck rubber packer in hole. Reamed casing down over rubber then drilled it out. HX csg set to the [illegible]

54.4' End shift @ 4:30 on 9/1/82 & begin shift @ 8:00 on 9/2/82. No water in hole—open to 49.3' then cuttings/slough

NOTE: RUN ABBREV.
D — DISTANCE DRILLED
C — CORE RECOVERED
CL — CORE LOSS
% — % CORE RECOVERED
LP — LONG PIECE OF CORE

WATER TEST NO. 3
35.5-54.4' PACKER—
Take 21.3 gpm @ 10 psi
" 32.0 " @ 20 - [illegible]
" 25.6 " @ 10 psi
Pressure gage stickup 1' above ground. 1.2' cuttings/slough in bottom hole.

WATER TEST NO. 4
50.4-74.4' PACKER—
Take 40.0 gpm @ 13 psi — max pump capacity. Pressure gage stickup 1.5' above ground.

NOTE: CORE LOSSES ATTRIBUTED TO WASHING & GRINDING.

WATER TEST

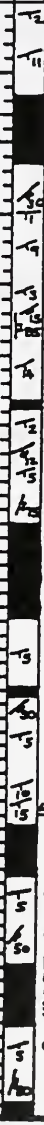
Interval	LOSS gpm	PRESSURE psi
35.5 – 54.4	21.3	10
	32.0	20
	25.6	10
54.4 – 74.4	40	13 Gauge

% RQD / ADVANCE – RECOVERY

Top	RUN	% RQD	D	C	CL	%	LP	Bottom
35.5'	RUN 9	0	4.3'	3.2'	1.1'	74	0.3'	39.4'
39.4'	RUN 10	34	5.0'	3.7'	1.3'	74	1.0'	44.4'
44.4'	RUN 11	30	5.0'	4.7'	0.3'	94	0.7'	49.4'
49.4'	RUN 12	22	5.0'	4.1'	0.9'	82	0.4'	54.4'
54.4'	RUN 13	0	5.0'	2.5	2.5	50	0.5	59.4'
59.4'	RUN 14	16	5.0'	4.7'	0.3	94	0.5	64.4'
64.4'	RUN 15	28	5.0'	3.2'	1.8	64	1.0	69.4'
69.4'	RUN 16	0	5.0'	2.8'	2.2	56	0.5	74.4'
74.4'	RUN 17	0						

ELEVATION / DEPTH

ELEVATION	DEPTH
3445.7	39
	40
	45
	50
	55
	60
	65
	70
3409.7	75



BOX/SAMPLE NO.

BOX 2
44.4
BOX 3 WOOD
64.0
BOX 4 PLASTIC

MATERIAL CLASSIFICATION — PHYSICAL DESCRIPTION

4.5-180.6' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER—

4.5-39' SILTSTONE-SANDSTONE INTERBEDDED—

30-39' SILTSTONE—
35.6-37.5' Black organic siltstone, decomposed, very soft. HCl-none.
CONTACT ARBITRARY

39-84.4' CLINKER (BAKED SILTSTONE-SANDSTONE INTERBEDDED) — Red & brown. Lightly & mod weathered, mod hard, intensely fractured—spaced avg 0.1' w/ 80% bedding & 20% joints. HCl-strong. Joints dip 15, 30 & 60°. Bedding dip 1-15°.

39-47.5' Drills to avg 0.1'; max 1.0' cores controlled 80% by bedding breaks.

47-47.5' decomposed, very soft.

47.5-84.4' Scattered fractures w/ black manganese film. A few bedding planes have fossil leaf imprints. Drills to avg. 0.2'; max 1.0' cores controlled 80% by bedding breaks.

50.9' slickensides dip 12°.
51-56.5' Mod. hard, red brown, fine-grained sandstone. HCl-strong.

58.8-59.4' & 60.5-60.8' Unweathered, gray, fine-grained sandstone. HCl-strong.

62-63' Fractures dip 5, 15, 30, 80° w/ 1mm white mineral coating—calcite & gypsum(?)

63.5-67.4' Fossil leaf imprints along bedding planes—closely spaced. HCl-none, absorptive. Drills to avg. 10-20mm "wafers" controlled by bedding.

67.4-69.4 Buff & red sandy siltstone HCl-strong. Drills to avg. 0.3' cores

69.4-78.5' Red-brown siltstone w/ fossil leaf imprints along bedding. HCl-none. Drills to avg 10mm "wafers" controlled by bedding.

HOLE NO. DH-101Z

SHEET 3 OF 5

DRILL LOG	PROJECT TONGUE RIVER – EXISTING DAM	JOB NO. 169.9	HOLE NO. DH-101Z

REMARKS / WATER LEVELS / WATER RETURN / WATER TESTS / DRILLING FLUID / CASING DEPTH

WATER TEST NO. 5
73.8 – 94.0' PACKER– Take 40.8gpm @10psi/2.5min then out of water – max. pump capacity, 1.5' slough/cuttings in hole, pressure gage stickup 16' above ground. Tore up rubber packer when coming out of hole – possibly packer was not seated.

84.4' End shift @4:30 on 9/2/82 – could not fill hole w/ 250± gal of water, NX casing @ 22'; begin shift @8:00 on 9/3/82. water level possibly 50'± uncertain on sounding using weighted tape, 9' cuttings/slough in bottom hole.

Run 20 hole is "caving" due to cuttings reports driller.

94.0' End shift @4:00 on 9/3/82, NX casing reamed to 85', begin shift @ noon 9/7/82 & ream NX casing to 94' & clean out, end shift @ 4:00 on 9/7/82 & begin shift @ 8:00 on 9/8/82. water level @ 72'.

102.7' Begin Run 23 using 10' core barrel – solid innertube – NX.

WATER RETURN

94 – 95'	100%	gray
95 – 96.5	"	black
96.5 – 101	"	gray
101 – 102	"	black
102 – 106	"	gray
106 – 107.5	"	black
107.5 – 108	NONE "caving"	
108 – 109	100%	black
109 – 133	"	gray
133 – 140.5	NONE – lost in coal/carbonaceous sl	
140.5 – 150.5	80%	gray
150.5 – 160.5	0–50%	gray
160.5 – 180.6	80%	gray

Water test Loss gpm	Pressure psi	% RQD	Advance / Recovery	Elevation	Depth	Box
73.8 ↓ 40± (MAX pump)	10	18	RUN 17 D-5.0' C-2.7' CL-2.3 %-54 LP-0.5 79.4'			BOX 4 78.5'
		32	RUN 18 D-5.0' C-5.0' CL-0 %-100 LP-0.5 84.4'	3400.3	80 84.4	BOX 5
		59	RUN 19 D-4.6' C-4.6' CL-0 %-100 LP-1.5 89.0'	3397.7	85 86.0	87.8'
↓ 94.0		84	RUN 20 D-5.0' C-5.0' CL-0 %-100 LP-1.2 94.0'	3390.7	90 94.0	BOX 6
NO TEST		90	RUN 21 D-5.0' C-5.0' CL-0 %-100 LP-1.1 99.0'		95	96.0'
0 0 0.3 0	20 30 40 20	76	RUN 22 D-3.7' C-3.7' CL-0 %-100 LP-1.2 102.7'		100	BOX 7
		70	RUN 23 D-7.9' C-7.9' CL-0 %-100 LP-1.8 110.6'	3377.9 3375.7	105 106.8 109.0 110	106.5' BOX 8
		89	RUN 24 D-10.0' C-10.0' CL-0 %-100 LP-2.5	3369.7	115	

MATERIAL CLASSIFICATION
PHYSICAL DESCRIPTION

4.5' – 180.6' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER –

39 – 84.4' CLINKER (BAKED SILTSTONE SANDSTONE INTERBEDDED) –

75.7 – 76.5' Red, fine-grained sandstone HCl-mod

76.5 – 78.0' Med hard, unweathered, gray siltstone. HCl-none. Fractures spaced avg 1", various orientations.

78.0 – 84.4 Med hard, red, brown & gray siltstone, unweathered, intensely fractured – spaced avg 0.2'.

CONTACT OPEN

84.4 – 86.0' SILTSTONE – Gray, unweathered, med hard, intensely fractured – avg 0.1' w/ 90% bedding. HCl-mod. Bedding planes very closely spaced w/ 1mm coal & organic siltstone beds spaced 1-20mm. Drills to avg. 0.1' cores controlled by bedding.

86.0 – 94.0' SANDSTONE – Fine & med-grained w/ some siltstone interbeds, gray, unweathered, med. hard, mod fractured. HCl-mod, mod cemented, Bedding dip 3-8°. Drills to avg 0.5', max 1.5' cores controlled 80% by bedding, 20% joints.
86.1 – 87.5' solid core
86.1 Red brown 10mm baked zone dip 6°.
88.5 – 91.6 Predom. gray siltstone
89.7 – 89.8' highly organic dip 5-8°
91.1 – 91.6' Coal seams 1-5mm along bedding dip 1-6°.

94.0 – 106.8' SILTSTONE – Gray, unweathered, med hard, mod fractured. HCl-weak, Scattered 1-10mm coal seams along bedding dip 1-15°. Slakes. Scattered fractures dip 30, 40 & 60°. Drills to avg 0.5', max 2.2' cores controlled 90% bedding & 10% joints.

95 – 96' Drills to avg 0.1' cores controlled by bedding w/ coal seams dip 2-5°.

101 – 102 Thin coal seams spaced 1-20mm v. intensely fractured. HCl-none. Drills to gravel sizes.

104.4' slickensides dip 20° & 50°.

105.0' slickenside dip 65°.

106.8 – 109.0' COAL – Black, unweathered, soft, very intensely fractured, brittle. HCl-none. Drills to gravel sizes controlled by a cubic (2 near vert & 1 near horiz) fracture pattern.

109 – 119.0' SILTSTONE – Gray, unweathered, med hard, intensely fractured. HCl-none. Thin coal & sandstone interbeds. Drills to avg 0.5', max 2.2' cores controlled by bedding dip 1-10°.
111.1 – 114.2 Carbonaceous siltstone & coal, slakes
111.2' very soft for 15mm

HOLE NO. DH-101Z

R.C.HARLAN AND ASSOCIATES

SHEET 4 OF 5

DRILL LOG	PROJECT TONGUE RIVER — EXISTING DAM	JOB NO. 169.9	HOLE NO. DH-101Z

REMARKS
WATER LEVELS
WATER RETURN
WATER TESTS
DRILLING FLUID
CASING DEPTH

WATER TEST NO.6
97.9-120.6' PACKER-
Take 0 gpm @ 20 psi
" 0 " @ 30 "
" 0.3 " @ 40 "
" 0 " @ 20 "
Pressure gage stickup 1.6' above ground surface. 0.2' slough/cuttings in hole.

NOTE: ALL WATER TEST FOR 5 MIN. AT EACH PRESSURE OR OTHERWISE NOTED.

130.6' End shift @ 4:30 on 9/8/82 & begin shift @ [redacted] on 9/9/82. Water level @ 72.

NOTE: "Z" AFTER HOLE NUMBER (DH-101Z) INDICATES PIEZOMETER INSTALLED.

WATER TEST NO.7
117.9-140.6' PACKER-
Take 0 gpm @ 20 psi
" 0 " @ 40 "
" 0 " @ 20 "
Pressure gage stickup 18.7' above ground surface.

WATER TEST NO. 8
137.9-160.6' PACKER-
Take 0 gpm @ 20 psi
" 0 " @ 40 "
" 0 " @ 60 "
" 0 " @ 20 "
Pressure gage stickup 2.0' above ground surface

NOTE: DRILL SEQUENCE IN COLLUVIUM WAS TO ADVANCE HOLE W/ 2½" SAMPLE BBL, AUGER TO BOTTOM OF SAMPLE, ADVANCE 2½" SAMPLE BBL. THEN 2" BBL, ADVANCE AUGER TO BOTTOM OF SAMPLE.

WATER TEST LOSS GPM	PRESSURE PSI	% ROD	ADVANCE / RECOVERY
0.0 0.0 0.3 0.0	20 30 40 20	89	RUN 24 D-10.6' C-10.6' CL-0 %-100 LP-2.2 120.6'
0.0 0.0 0.0	20 40 20	98	RUN 25 D-10.0' C-10.0' CL-0 %-100 LP-2.2' 130.6
		97	RUN 26 D-10.0' C-10.0' CL-0 %-100 LP-1.9 140.6'
137.9 ↑ 0.0 0.0 0.0 0.0	 20 40 60 20	100	RUN 27 D-10.0' C-10.0' CL-0 %-100 LP-2.5 150.6'
		94	RUN 28 D-10.0' C-10.0' CL-0 %-100 LP-2.2

ELEVATION	DEPTH
3365.7	119.0
	120
	125
	130
3353.6	131.1
	135
	140
	145
3339.2	145.5
	150
3329.7	155

GRAPHIC LOG

BOX/SAMPLE NO.
115.0
BOX 9
125.0
BOX 10
134.8
BOX 11
144.6
BOX 12
154.4

MATERIAL CLASSIFICATION
PHYSICAL DESCRIPTION

4.5 - 180.6' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER-

109.0-119.0' SILTSTONE-
116-117' Carbonaceous w/thin coal seams.

CONTACT GRADATIONAL
119.0-131.1 SANDSTONE- Fine- & med grained, gray, unweathered, med hard, mod fractured-spaced avg 1.0', max 2.0' controlled by bedding dip 2 Scattered siltstone interbeds, dip 3-15°. slightly friable.
119.0-124.8'-/HCl-strong.

124.8-127' Gray, med hard siltstone w/ 1-10mm coal & carbonaceous interbeds. Breaks along bedding. HCl-none.

127-131.1' HCl-none & weak.

131.1-145.5' SILTSTONE- Gray, unweathered, med. hard, mod fractured HCl-none to mod. Scattered sandstone & thin coal interbeds.

132.7-135.5' Coal & carbonaceous seams, 1-10mm along bedding dip 3-10°. Breaks along bedding w/ light hammer blow. Drilled to avg 0.2', max 0.5' cores controlled 90% by bedding & 10% joints. HCl-none.

135.5-145.5' HCl-weak to mod. Drills to avg 1.0', max 2.8' cores controlled by bedding breaks.

143.0-145.5' small cross bedding features highlighted by thin (1mm) carbonaceous seams.

145.5-180.6' SANDSTONE- Fine-grained, gray, unweathered, mod hard, mod fractured. HCl-strong Scattered gray siltstone interbeds & dark gray, 1-3mm carbonaceous layers dip 0-20°. Local small cross bedding features.
Drills to avg 1-2', max 3.9' cores controlled 90% by bedding, 10% joints. Core is mod. cemented & adsorptive.

145.5-163' HCl-strong.

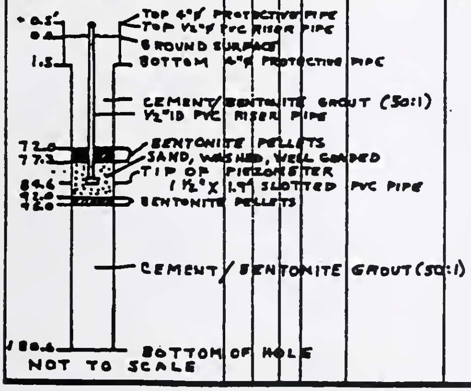
HOLE NO. DH-101Z

R.C.HARLAN AND ASSOCIATES

SHEET 5 OF 5

DRILL LOG	PROJECT TONGUE RIVER — EXISTING DAM	JOB NO. 169.9	HOLE NO. DH-101Z

REMARKS WATER LEVELS WATER RETURN WATER TESTS DRILLING FLUID CASING DEPTH	WATER TEST LOSS GPM	WATER TEST PRESSURE PSI	% RQD	ADVANCE / RECOVERY	ELEVATION	DEPTH	BOX/SAMPLE NO.	MATERIAL CALSSIFICATION PHYSICAL DESCRIPTION
WATER TEST NO. 9 157.9–180.6′ PACKER– Take 0 gpm @ 40 psi " 0.08 " @ 60 " " 0 " @ 40 " Pressure gage at ground surface. Gage is Ashcroft in 1 psi increments to 100 psi.	0 0 0 0	20 40 60 20	94	RUN 28 D-10.0′ C-10.0 CL-0 %-100 LP-3.8′			BOX 13	45–180.6′ PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER– 145.5–180.6′ SANDSTONE –
				160.6′		160		
	0 0.1 0	40 60 40	100	RUN 29 D-10.0′ C-10.0′ CL-0 %-100 LP-2.0′			162.5	163–178.5′ HCl–weak & mod. 162.5–163.2′ carbonaceous layers, 1mm, spaced 5mm.
						165	BOX 14	
170.6′ End shift @ 4:00 on 9/9/82 & begin shift @ 8:00 on 9/10/82. Water level @ 72′.				170.6		170		
			98	RUN 30 D-10.0′ C-10.0′ CL-0 %-100 LP-3.7′			172	
						175	BOX 15	
180.6′ End shift @ 6:00 on 9/10/82 w/ piez. pipe installed, all but 5′ of csg. pulled, bentonite pellets @ 73.5′. Begin shift @ 8:00 on 9/11/82, hole @ 73.5′ add pellets to 72.0, grout hole, pull csg & move to DH-102Z begin @ 12:30 pm.					3304.1	180 180.6		172.5–180.6′ HCl–strong, very fine-grained.



BOTTOM OF HOLE
DEPTH — 180.6′
ELEV. — 3304.1′

NOTE: DRILL HOLE LOCATION & ELEVATION FROM 1 INCH = 200 FEET MAP FURNISHED IN JAN. 1983 BY DNRC, "DRILL HOLE LOCATION, TONGUE RIVER DAM, BIG HORN COUNTY".

HOLE NO. DH-101Z

R.C. HARLAN AND ASSOCIATES

SHEET 1 OF 3

DRILL LOG	PROJECT: TONGUE RIVER — EXISTING DAM		JOB NO. 169.9	HOLE NO. DH-102Z
SITE / LOCATION: LEFT ABUTMENT.	BEGUN: 9/11/82	COMPLETED: 9/14/82	HOLE SIZE: 3"	ANGLE FROM HORIZ. & BEARING: VERTICAL
COORDINATES: N. 25,416 E. 84,460	GROUND WATER DEPTH / EL.		GROUND EL. 3433.4'	TOP OF ROCK DEPTH / EL. 24.5'/3408.9'
DRILLING CONTRACTOR: NORTHERN TESTING LABORATORIES	CORE REC. LENGTH / %: 65.0'/66.0' = 98%	SAMPLES: 19	CORE BOXES: 7	BOTTOM OF HOLE DEPTH / EL. 94.3'/3339.1'
DRILL MAKE AND MODEL: MOBILE B-50	LOGGED BY: CHARLES I. TRANTHAM			

REMARKS — WATER LEVELS, WATER RETURN, WATER TESTS, DRILLING FLUID, CASING DEPTH

DRILLER — MORRIS ORMOND
HELPER — CLINT NELSON

Hole drilled on alluvial flat area north of reservoir & south of access road.

Move from DH-101Z, set up, & begin drilling @ 3:00 on 9/11/82.

6.0' End shift @ 4:30 on 9/11/82 & begin shift @ 8:00 on 9/12/82

WATER TEST NO. 1
6.0' OPEN END TEST — Take 0.1gpm for 5min. Bottom NX casing @ 6.0' & stickup 0.5'

WATER TEST NO. 2
9.0–11.0' — MAINTAIN HEAD Open hole is 2½" ∅. Take 0.2gpm for 5min w/seepage around outside of NX casing set @ 9' w/0.5' stickup. Maintain water level @ ground

WATER TEST NO. 3
14.0' OPEN END TEST — Take 0.1gpm for 5min to maintain level @ ground surface. Bottom NX csg. @ 14' w/ 0.5' stickup.

WATER TEST NO. 4
19.0–19.1' OPEN END TEST — Take 6.3gpm for 5min to maintain level @ ground surface — leakage around outside of NX casing — bottom @ 19' & 0.5' stickup

WATER TEST NO. 5
22.0' OPEN END TEST — Take 4.6gpm for 5min. Bottom NX casing @ 22.0' & 2.3' stickup — no leakage around casing.

WATER TEST NO. 6
27.0' OPEN END TEST — Take 38.0gpm for 3min — out of water in tank. Bottom of NX casing @ 27.0' & 0.5' stickup w/ water level maintained @ ground surface w/ no visible leakage around csg.

23.5–25.4' Shelby 2½", bent end of tube.

27.0' End shift @ 4:30 on 9/12/82 & begin shift @ 8:00 on 9/13/82. Water level @ 21'

SAMPLER	BLOWS / 6" (RQD)	ADVANCE / RECOVERY	ELEVATION	DEPTH	GRAPHIC LOG	BOX/SAMPLE NO.
MOD CALIF 3"OD	8 21 24	18"/17"			ML	1L
SPLIT BBL 2½"OD	18 30 43	18"/18"				2S
MOD CALIF 3"OD	17 27 62	18"/18"			SC CL	3L
SPLIT BBL 2½"OD	17 27 43	18"/18"		5		4S
SPLIT BBL 2½"OD	8 6 6	18"/18"			ML	5S
STD PEN 2"OD	2 3 5	18"/18"				6S
SHELBY 2½"OD	HYD LT.	24"/24"		10		7S
SPLIT BBL 2½"OD	3 6 8	18"/18"			MH	8S
STD PEN 2"OD	3 4 5	18"/18"				9S
SHELBY 2½"OD	HYD LT.	24"/24"		15	SM MH	10S
SPLIT BBL 2½"OD	2 6 6	18"/15"			SC CL	11S
STD PEN 2"OD	11 55 14	18"/9"				12S
SPLIT BBL 2½"OD	11 6 8	18"/10"		20		13S
STD PEN 2"OD	6 13 8	18"/3"				14S
SPLIT BBL 2½"OD	8 8 4	18"/3"				15S
SHELBY 2½"OD	HYD HYD	23"/23"	3408.9	24.5 25		16S
SPLIT BBL 2½"OD	7 20 27	19"/9"				17S
SHELBY 2½"OD	HYD	10"/10"				18S
SPLIT BBL	100	5"/6"				19S
	33	28.3' RUN 1 R-28" C-48" a-60" b-82 [illegible] 0.7		30	73 45 7 Φ 3	BOX 1
	66	33.0' RUN 2 R-6.0' C-6.0'	3398.4'	35		

MATERIAL CLASSIFICATION — PHYSICAL DESCRIPTION

0 – 24.5' QUATERNARY ALLUVIUM

0 - 3.5' BROWN SANDY SILT — Loose, dry; approx 60% silt, 30% sand, 10% gravel. Scattered platy sandstone fragments.

3.5-6.0' BROWN CLAYEY SAND — Dense, damp; approx 50% sand, 30% gravel, 20% clay. Angular to subround sandstone & limestone fragments & a few clinkers. Toughness - high. Dilat. - none.

6.0-13.0' BROWN SANDY SILT - Firm, moist; approx 50% silt, 50% very fine & fine sand. Toughness - low; Dilat. - quick. Scattered rootlets.

10' Increase in toughness to med.

13.0-15.5' BROWN SILTY SAND — Med. dense, moist; approx 60% fine sand, 40% silt. Dilat. - quick.

15.5- 24.5' BROWN CLAYEY SAND— Firm, moist; approx 70% sand, 20% clay, 10% gravel. Stratified.

19.7-20.0' silty sand layer

20.0' Increase in % gravels to approx 60% sand, 30% gravels, 10% clay.

Material is stratified w/ silt & sand layers to 3".

24.5- 94.3' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER-

24.5 - 43.5' SILTSTONE - Brown, decomposed to mod. weathered, soft & mod. hard, intensely fractured. Scattered thin, fine-grained sandstone interbeds. Bedding dip 0-13°, minor cross bedding. HCl - weak.
Drills to avg 0.3', max 0.7' cores controlled 80% by bedding & 20% joints. Some fractures w/ black manganese? film. 31.3' Soft rock & clay -1".

33.0- 34.5' Gray brown, lightly weathered, hard, well cemented sandstone. HCl - strong.

HOLE NO. DH-102Z

R.C. HARLAN AND ASSOCIATES

SHEET 2 OF 3

DRILL LOG	PROJECT TONGUE RIVER — EXISTING DAM	JOB NO. 169.9	HOLE NO. DH-102Z

REMARKS — WATER LEVELS, WATER RETURN, WATER TESTS, DRILLING FLUID, CASING DEPTH

28.3' Begin NX coring.

Run 1 & 2 used NX-5' long core barrel w/ split barrel innertube.

Run 3 begin using 10' core barrel.

33.8' Bottom NX casing, reamed after Run 1.

NOTE: SAMPLE ABBREVIATION—
S – SHELBY
J – JAR
L – BRASS LINER–6"

WATER RETURN
28.3–94.3' None — uncertain of loss area — above 37.3', possibly NX casing not sealed.

WATER TEST NO. 7
37.3–55.0' PACKER—
Take 7.6 gpm @ 5 psi
" 8.6 " @ 10 "
" 7.1 " @ 5 "
Pressure gage stickup 9.0' above ground surface.

NOTE: TYPICAL OVERBURDEN DRILL SEQUENCE IS TO ADVANCE CASING TO BOTTOM OF HOLE & CLEAN OUT WITH ROLLER BIT, HYDRAULICALLY PUSH SHELBY TUBE OR DRIVE THE SPLIT-BARREL SAMPLER USING A 140 POUND SAFETY HAMMER DROPPED 30" BY A 1"ø ROPE WITH 3 WRAPS ON AN 8"ø CATHEAD. WHERE HOLE STANDS OPEN THE 3"OD, 2½"OD & 2"OD SAMPLERS WERE ADVANCED IN SEQUENCE WITHOUT ADVANCING CASING.

NOTE: RUN ABBREV.
D – DISTANCE DRILLED
C – CORE RECOVERED
CL – CORE LOSS
% – % RECOVERED
LP – LONG PEICE OF CORE

WATER TEST NO. 8
52.4–73.1' PACKER—
Take 0 gpm @ 20 psi
" 0 " @ 40 "
" 0 " @ 20 "
Pressure gage stickup 1.1' above ground surface. Packer catching @ 40'.

NOTE: DARK AREAS IN GRAPHIC LOG COLUMN INDICATES NO MATERIAL RECOVERY.

WATER TEST (LOSS GPM / PRESSURE PSI)

LOSS GPM	PRESSURE PSI
37.3	
7.6	5
8.6	10
7.1	5
52.4 ↑	
0	20
0	40
0	20
↓ 73.1	

% RQD / ADVANCE / RECOVERY

% RQD	ADVANCE / RECOVERY
66	RUN 2 D-5.0' C-5.0' CL-0 %-100 LP-0.5' 38.8'
83	RUN 3 D-7.1' C-7.1' CL-0 %-100 LP-2.1' 45.9'
93	RUN 4 D-9.1' C-9.1' CL-0 %-100 LP-1.3' 55.0'
87	RUN 5 D-10.2' C-10.2' CL-0 %-100 LP-2.5' 65.2'
83	RUN 6 D-9.9' C-9.9' CL-0 %-100 LP-1.4' ↓ 75.1'

ELEVATION / DEPTH

ELEVATION	DEPTH
	40
3389.9	43.5
	45
	50
	55
	60
3370.4	63.0
	65
	70
3361.9	71.5
3359.4	74.0
3358.4	75

GRAPHIC LOG

BOX/SAMPLE NO.

BOX 1
38.8
BOX 2
47.6
BOX 3
57.1
BOX 4
66.4
BOX 5
↓ 75.1

MATERIAL CLASSIFICATION — PHYSICAL DESCRIPTION

24.5–94.3' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER—

24.5–43.5' SILTSTONE—

40–41' Gray & brown, mod. weathered, mod hard, mod. cemented sandstone. HCl–mod.
41' Film of clay along 15° contact–open.
41–43.5' HCl–mod.

43.5–63.0' SILTSTONE – Gray, unweathered, mod. hard, mod. fractured. HCl – weak to strong. Scattered thin sandstone interbeds & thin carbonaceous seams. Drills to avg. 1', max 3' cores controlled 75% by bedding & 25% joints.

44.6 crumbly, brittle, black coal seam, 10 mm, dip 7°.

47.8' Black coal seam 2 mm, & 20 mm dk. gray carbonaceous siltstone.
47.8–50.2' HCl–strong.
50.2–51.0' Slightly friable, mod hard, brown sandstone. HCl–strong.

52.2' Thin clay seam & 1 mm coal dip 14°.

53.6' coal seam, 10 mm dip 20°.

53.8–54.8' slightly friable, mod hard, unweathered, gray sandstone. HCl–strong.

55.0–55.1' Decomposed claystone — molds to CL w/ finger pressure.

55.3–59.0' Slightly friable, mod hard, gray, v. fine-grained sandstone. HCl–strong.
58.4' Film clay on 10° dip bedding.

59.0–63.0' Dark gray, carbonaceous w/ 1–10 mm coal seams, HCl–none to mod. Drills to avg 0.5' cores controlled by bedding.
61.0' Clay seam (10 mm) – decomposed claystone?

63.0–71.5' SANDSTONE — Fine & some med-grained, gray, unweathered, mod hard, mod fractured. Scattered thin carbonaceous layers & coal seams. HCl–none, absorptive. Drills to avg 1.0', max 1.4' cores controlled by approx 80% bedding & 20% joints.

68.5–71.5' Dark gray, w/ many thin carbonaceous layers.
68.5 Coal seam (10 mm) dip 10°

71.5' Fossil clam(?) imprint on 5° bedding – contact broke open on drilling.

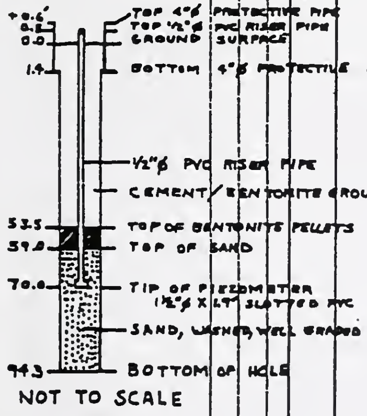
71.5–74.0' COAL — Black, unweathered, mod hard, intensely fractured. HCl–none, brittle. Drills to avg 0.3', max 0.5' cores controlled 90% by bedding.

74.0–83.5' SILTSTONE – Gray w/ thin sandstone & coal interbeds, unweathered, mod hard

HOLE NO. DH-102Z

DRILL LOG	PROJECT TONGUE RIVER — EXISTING DAM	JOB NO. 169.9	HOLE NO. DH-102Z

REMARKS WATER LEVELS WATER RETURN WATER TESTS DRILLING FLUID CASING DEPTH	WATER TEST LOSS GPM	WATER TEST PRESSURE PSI	% RQD	ADVANCE / RECOVERY	ELEVATION	DEPTH	GRAPHIC LOG	BOX/SAMPLE NO.	MATERIAL CALSSIFICATION PHYSICAL DESCRIPTION
75.1' End shift @ 4:30 on 9/13/82 & begin shift @ 8:00 on 9/14/82. Water level @ 21'. NOTE: CORE LOSSES ATTRIBUTED TO WASHING & GRINDING. NOTE: ALL BEDDING & JOINT INCLINATIONS ARE WITH CORE AXIS. NOTE: ALL WATER TEST FOR 5 MINUTES AT EACH PRESSURE UNLESS OTHERWISE NOTED. NOTE: "Z" AFTER HOLE NUMBER (DH-102Z) INDICATES PIEZOMETER INSTALLED. WATER TEST NO. 9 76.6-94.3' PACKER- Take 1.4 gpm @ 20 psi " 2.4 " @ 40 " " 1.3 " @ 20 " Pressure gage stickup 2.0' above ground surface 94.3' End shift @ 4:30 on 9/14/82 w/piezometer partially installed - sand, bentonite & begin shift @ 8:00 on 9/15/82. Complete piezometer @ 10:00 & begin move to DH-111E.	76.6 ↕ 1.4 2.4 1.3	20 40 20	88 100	RUN 7 D-10.0 C-10.0 CL-0 %-100 LF-12 85.1 RUN 8 D-9.2 C-9.2 CL-0 %-100 LF-35	3349.9 3339.1	80 83.5 85 90 94.3	3 15 6 5 3 35 2 5 3 10 5 2 2 10 15 2 10 10 15	[illegible] BOX 6 [illegible] BOX 7	24.5-94.3' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER — 74.0-83.5' SILTSTONE — Gray, unweathered, med hard, mod fractured. HCl-none. Scattered thin sandstone & coal interbeds. Drills to avg 0.5', max 1.2' cores controlled 80% by bedding, 20% joints. 74-76' soft, molds to clay w/fingers. 76.2-77.0' coal w/ thin clay seams. 77.2' slickensides dip 45°. 77.4' slickensides dip 55°. 83.5-94.3' SANDSTONE — Fine & med-grained, unweathered, mod hard, mod fractured, slightly friable. Locally thin siltstone interbeds. Bedding dip 1-20° w/local cross bedding. Drills to avg 1', max 3.3' cores controlled approx 80% by bedding & 20% joints. 83.5-88' HCl - mod. 85.0-85.1' Decomposed claystone - molds to CL. 88-92' HCl - none & weak, absorptive. 92-94.3' HCl - mod & strong. 94-94.3' Soft siltstone.



NOT TO SCALE

BOTTOM OF HOLE
DEPTH — 94.3'
ELEV. — 3339.1'

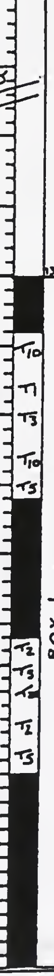
NOTE: DRILL HOLE LOCATION & ELEVATION FROM 1 INCH = 200 FEET MAP FURNISHED IN JAN 1983 BY DNRC, "DRILL HOLE LOCATION, TONGUE RIVER DAM, BIG HORN COUNTY".

HOLE NO. DH-102Z

R.C. HARLAN AND ASSOCIATES

SHEET 1 OF 4

DRILL LOG	PROJECT TONGUE RIVER – EXISTING DAM		JOB NO. 169.13	HOLE NO. DH-120AZ
SITE / LOCATION LEFT ABUTMENT - SPILLWAY (LT. BANK)	BEGAN 3-27-84	COMPLETED 4-9-84	HOLE SIZE 4", NX	ANGLE FROM HORIZ. & BEARING VERTICAL
COORDINATES BUREAU OF RECLAMATION U.S. DEPARTMENT OF THE INTERIOR	GROUND WATER DEPTH / EL.		GROUND EL. 3470'±	TOP OF ROCK DEPTH / EL. 7.5' / 3462.5'±
DRILLING CONTRACTOR BUREAU OF RECLAMATION U.S. DEPARTMENT OF INTERIOR	CORE REC. LENGTH / % $\frac{105.5'}{143.0'}$ = 74%	SAMPLES 0	CORE BOXES 7	BOTTOM OF HOLE DEPTH / EL. 273.0' / 3192.0'±
DRILL MAKE AND MODEL FAILING 1500 — TRUCK MOUNTED	LOGGED BY: CHARLES I. TRANTHAM			

REMARKS WATER LEVELS WATER RETURN WATER TESTS DRILLING FLUID CASING DEPTH	WATER TEST LOSS GPM	WATER TEST PRESSURE PSI	% RQD	ADVANCE / RECOVERY	ELEVATION	DEPTH	GRAPHIC LOG	BOX/SAMPLE NO.	MATERIAL CLASSIFICATION PHYSICAL DESCRIPTION
DRILLER - JIM McGAUGHLIN HELPER - MIKE McNAMEE Hole located on left abutment on left bank, of spillway, approx. 8' north of DH-120. Crew moved from DH-120 to DH-120AZ and drilled to 30.0' end shift on 3-27-84. Advanced hole from 30-70' & N casing to 62' end shift 3-28-84. Advanced H casing to 63.5' end shift 3-29-84. 4-DAY BREAK. Advanced hole from 70-74' & casing to 73' end shift 4-3-84. Advanced hole from 74-158' & casing to 82.5 end shift 4-4-84.	128.0'					BREAK IN SCALE			0.0 – 7.5' QUATERNARY COLLUVIUM (CO) SILTY SAND (SM,MH): BROWN. 7.5 – 273.0' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER 7.5 – 84.5' CLINKER (CK): 84.5 – 124' SILTSTONE (SI): NOTE: REFER TO DH-120 DRILL LOG FOR DETAILS 0-1
0-50' Drilled w/ 3 7/8" rock bit. 30' Bottom H casing. 50-130' Drilled w/ 2 15/16" rock bit. 82.5 Bottom N casing. 130.0' Begin NX (3" OD) core drilling using 10' long wireline barrel – core 1-15/16" diameter.	0	50	33	130.0' RUN 1 D-8.0' C-6.0' CL-2.0' % 75 LP-1.5'	3340	130 135		130.0'	124 — 144' SANDSTONE (SS): GRAY. Silty, fine-grained - subrounded & subangular, scattered black grains, thinly bedded. Unweathered, slightly & mod. hard, No & weak reaction w/ HCl, mod & slightly friable. Closely fractured. Drills to avg. 0.3', max 1.3' cores controlled mainly by bedding - dip 1-10°. 136-138' Soft & slightly hard, absorptive.
WATER TEST NO. 1 PACKER TEST 128-138'. Take 0 gpm @ 50 psi. WATER TEST NO. 2 PACKER TEST 138-148'. Take 0 gpm @ 50 psi. WATER TEST NO. 3 PACKER TEST 148-163'. Take 0 gpm @ 50 psi. NOTE: DARK AREAS IN GRAPHIC LOG COLUMN INDICATES NO CORE RECOVERY.	0	50	13	138.0' RUN 2 D-10.0' C-5.0' CL-5.0' %-50 LP-1.5'	3326	140 144 145		BOX 1	Contact - bedding, arbitrary. 144 – 202.5' SANDSTONE (SS): GRAY. Fine-grained - subrounded & subangular, scattered black grains and tan (feldspar?) grains - locally along bedding in bands, med. bedding. Unweathered, mod. hard, weak reaction w/ HCl, mod. to extremely friable. Closely fractured. Drills from 0.1' to 0.6, avg 0.2' cores controlled mainly by bedding, dip 1-25°. Breaks easy along bedding & normal to core. Scattered carbonaceous bands to 10 mm.
NOTE: CORE LOSSES ATTRIBUTED TO WASHING & GRINDING - ASSUMED IN SOFTER EXTREMELY TO HIGHLY FRIABLE ROCK.	0	50	0	148.0' RUN 3 D-10.0' C-0.3' CL-9.7' %-3 LP-0.1'		150 155			144-163' No reaction w/ HCl, absorptive. 148-158 Core recovery 0.3' – assumed extremely friable – core washes away.

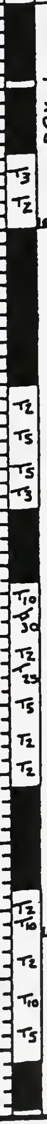
HOLE NO. DH-120AZ

R.C. HARLAN AND ASSOCIATES

SHEET 2 OF 4

DRILL LOG	PROJECT TONGUE RIVER —EXISTING DAM	JOB NO. 169.13	HOLE NO. DH-120AZ

REMARKS WATER LEVELS WATER RETURN WATER TESTS DRILLING FLUID CASING DEPTH	WATER TEST LOSS gpm	WATER TEST PRESSURE psi	% RQD	ADVANCE / RECOVERY	ELEVATION	DEPTH	BOX/SAMPLE NO.	MATERIAL CALSSIFICATION PHYSICAL DESCRIPTION
158.0' End shift on 4-4-84 & begin shift on 4-5-84. 158-173' Driller reports core losses due to washing	0	50		RUN 3 D-10.0' C-0.3' CL-9.7' %-3 LP-0.5' 158.0'			BOX 1	7.5-273.0' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER 144-202.5' SANDSTONE (ss): GRAY.
			34	RUN 4 D-5.0' C-2.3' CL-2.7' %-46 LP-0.5 163.0'		160		
WATER TEST NO. 4. PACKER TEST 163-173'. Take 2gpm @ 50psi. WATER TEST NO. 5. PACKER TEST 173-183'. Take 1gpm @ 50psi. NOTE: ALL BEDDING & JOINT INCLINATIONS ARE WITH CORE AXIS. NOTE: ALL WATER TESTS ARE 5 MINUTES.	2	50	17	RUN 5 D-10.0' C-4.4' CL-5.6' %-44 LP-0.5 173.0'		165 170		163-202.5' Week reaction w/HCl.
NOTE: "Z" AFTER HOLE NUMBER (DH-120AZ) INDICATES PIEZOMETER INSTALLED. NOTE: RUN ABBREV. D- DEPTH DRILLED C- CORE RECOVERED CL- CORE LOSS %- PERCENT RECOVERY LP- LONG PIECE OF CORE	1	50	0	RUN 6 D-10.0' C-7.4' CL-2.6' %-74 LP-0.2' 183.0'		175 180	BOX 2	173-183' Black bands 1-5mm along bedding, dip 2-25°, areas of very thin bedding
WATER TEST NO. 6 PACKER TEST 183-193'. Take 2gpm @ 50psi WATER TEST NO. 7. PACKER TEST 193-203'. Take 2gpm @ 50psi. 193.0' End shift on 4-5-84 & begin shift on 4-6-84 Water level @ 98.0'.	2	50	4	RUN 7 D-10.0' C-6.3' CL-3.7' %-63 LP-0.4' 193.0'		185 190	BOX 3	
	2	50	0	RUN 8 D-10.0' C-8.3' CL-1.7'		195		



HOLE NO. DH-120AZ

SHEET 3 OF 4

DRILL LOG	PROJECT TONGUE RIVER — EXISTING DAM	JOB NO. 169.13	HOLE NO. DH-120AZ

REMARKS: WATER LEVELS, WATER RETURN, WATER TESTS, DRILLING FLUID, CASING DEPTH

NOTE: No water return drilling through clinker. Got return at 82.5' on setting casing. Generally water return approx 70% — gray or rock color — black in coal. Lost all water @ 259.6'. In core there are 1/4" open (non stained) vertical joints. Water test data indicates area tight — possibly leaking beneath casing or between 150'-160' — when sand backfilling reached 150' water came to surface.

WATER TEST NO. 8
PACKER TEST 203-213'.
Take 0 gpm @ 50 psi.

WATER TEST No. 9
PACKER TEST 213-223'.
Take 0 gpm @ 50 psi.

WATER TEST No. 10
PACKER TEST 223-233'.
Take 2.5 gpm @ 50 psi.

WATER TEST No. 11
PACKER TEST 233-243'.
Take 26 gpm @ 50 psi — max. pump.

NOTE: WATER LEVELS

1. DURING DRILLING 97-107'

2. 4-25-84 #1(626')-94.5'
4-25-84 #2(14')-83.7'

233.0' End shift on 4-6-84 & begin shift on 4-7-84. Water level @ 97.7'.

WATER TEST LOSS gpm	PRESSURE psi	% RQD	ADVANCE / RECOVERY
2	50	0	RUN 8 D-10.0' C-8.3' CL-1.7' %-83 LP-0.5' 203.0
0	50	76	RUN 9 D-10.0' C-9.3' CL-0.7' %-93 LP-1.3' 213.0
0	50	11	RUN 10 D-10.0' C-7.2' CL-2.8' %-72 LP-0.5' 223.0
2	50	0	RUN 11 D-10.0' C-9.0' CL-1.0' %-90 LP-0.2' 233.0
26	50	72	RUN 12 D-10.0' C-10.0' LP-1.7'

ELEVATION	DEPTH
	200
3267.5	202.5
	205
	210
	215
	220
	224
	225
	229.5
	230
3237.4	232.6
	235

GRAPHIC LOG: 30, 5, 5, 5, 5, 1, 5, 22, 15, 5, 15, 15, 15, 10, 15, 10, 5, 5, 15, 10, 10, 5, 10, 5, 5, 7

BOX/SAMPLE NO.: BOX 3; 208.0; BOX 4; 226.5; BOX 5

MATERIAL CLASSIFICATION — PHYSICAL DESCRIPTION

7.5 — 273.0' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER

144 - 202.5' SANDSTONE (SS): GRAY.

Contact - bedding - arbitrary.

202.5 — 224' SANDSTONE (SS): GRAY. Carbonaceous siltstone interbeds. Fine-grained, w/ 1mm - 2" carbonaceous bands along bedding - tight w/ some breaks on drilling, thinly bedded. Unweathered, mod. hard, no reaction w/ HCl on siltstone & weak reaction on sandstone, slightly friable. Closely fractured. Drills to avg. 0.5', max. 1.3' controlled by bedding breaks. Sandstone is locally mod. friable & absorptive.

223.0' - Gray clay 0.1' at top of run — cuttings?

224 - 229.5' SANDSTONE (SS): GRAY. Fine-grained - subrounded & subangular, scattered black grains & tan (feldspar?), mod. bedded. Unweathered, mod. hard, mod. reaction w/ HCl, mod. friable. Extremely fractured. Drills to avg. 0.1' cores controlled by bedding breaks. Core washes to smaller diameter, absorptive.

229.5 - 232.6' SANDSTONE (SS): GRAY. Silty, fine-grained, closely bedded. Unweathered, mod. hard, slightly friable. mod. reaction to HCl. Drills to avg. 0.1' cores controlled by bedding dip 7-5°. Contact - bedding dip 5° - tight.

232.6 - 245.7 COAL (CO) WALL RED: BLACK. 232.6 - 235 Closely fractured. Drills to avg 0.1', max 0.3' cores controlled by bedding & joints.

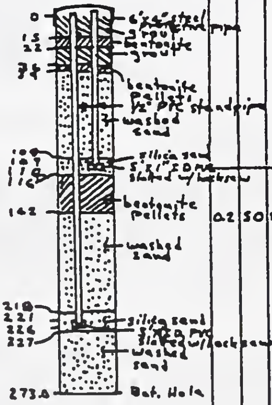
HOLE NO. DH-120AZ

R.C. HARLAN AND ASSOCIATES

SHEET 4 OF 4

DRILL LOG	PROJECT TONGUE RIVER— EXISTING DAM	JOB NO. 169.13	HOLE NO. DH-120AZ

REMARKS WATER LEVELS WATER RETURN WATER TESTS DRILLING FLUID CASING DEPTH	WATER TEST LOSS gpm	WATER TEST PRESSURE psi	% RQD	ADVANCE / RECOVERY	ELEVATION	DEPTH	BOX/SAMPLE NO.
WATER TEST NO. 12. PACKER TEST 243-253'. Take 12gpm @ 50psi. WATER TEST NO. 13. PACKER TEST 253-263'. Take 1gpm @ 60psi. WATER TEST NO 14 PACKER TEST 253-273' Take 0.2gpm @ 50psi. WATER TEST NO 15 PACKER TEST 223-273' Take 10.2gpm @ 30psi Take 25.2gpm @ 50psi Take 10.6gpm @ 30psi	26	50	72	RUN 12 D-10.0' C-10.0' CL-0 %-100 LP-6.7 243.0		240	BOX 5 242.5
WATER TEST NO 16 GRAVITY - OPEN HOLE +1.0 - 273.0' (2 7/8" hole) Take 60± gpm - 1min test. Bottom of N casing @ 82.5'. 253.0' end shift on 4-7-84 & begin shift on 4-8-84. 263.0' End shift on 4-8-84 & begin shift on 4-9-84. Water level @ 106.0' 273.0' End shift on 4-9-84 & begin piezometer installation - & begin shift on 4-10-84. Water level at 106.9'. Installed lower piezometer (open tube PVC) tip @ 226' on 4-10-84. Installed upper piezometer tip @ 114' on 4-11-84. Backfilled hole on 4-12-84 & completed installation 4-17-84 & moved to DH-121.	12	50	39	RUN 13 D-10.0' C-10.0' CL-0 %-100 LP 4.5 253.0	3224.3	245 245.7 250	BOX 6
	1	50	85	RUN 14 D-10.0' C-10.0 CL-0 %-100 LP-26 263.0		255 260	[illegible]
	0.2	50	85	RUN 15 D-10.0' C-10.0 CC-0 %-100 LP-23 273.0	3197.0	265 270 273	BOX 7



NOT TO SCALE

MATERIAL CLASSIFICATION

PHYSICAL DESCRIPTION

7.5-273.0' PALEOCENE FORT UNION FORMATION, TONGUE RIVER MEMBER

232.6-245.7' COAL(ca) WALL BED: BLACK. Scattered fossil leaves. Unweathered, mod. hard, no reaction w/ HCl, nonfriable. Fractures spaced 0.1-1.0', smooth to 2mm relief. Brittle.

235-245.7' Mod. fractured. Drills to avg. 0.5', max 1.8' cores, controlled by bedding & joints.

Contact - bedding, dip 2°, tight.

245.7-273.0' SILTSTONE(sl): GRAY. Sandy - fine-grained, subrounded & subangular, thinly bedded - 1mm to 6"; scattered 1-3mm black carbonaceous bands. Unweathered, mod. hard, weak reaction of siltstone w/ HCl & mod. reaction w/ sandstone, slightly friable. Drills to avg 0.5-1.6' cores, controlled by bedding.

246.0-246.2 Coal seam, contacts dip 2-5°.

246.2-250.5' massive - drills to 4.5' long peice, thinly bedded - avg 0.2'.

250.5-253.0' Thinly bedded, banded, drills to avg. 0.4' controlled by bedding.

253.6-253.8' Extremely carbonaceous.

254.5-255.5' scattered 1/2" calcite filled vugs.

256.4-257' Highly carbonaceous.

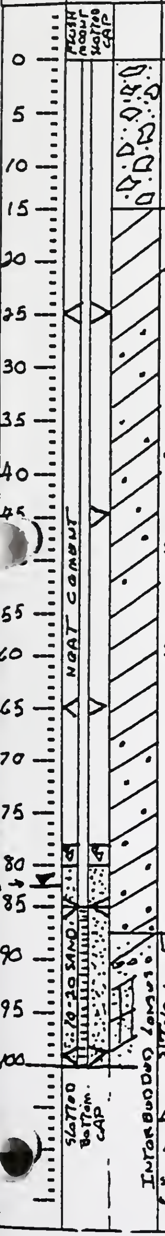
272.0 - Gray clay 5mm (cuttings?) along bedding dip 2°.

BOTTOM OF HOLE
DEPTH - 273.0' ELEV - 3197.0

HOLE NO. DH-120AZ

Terracon

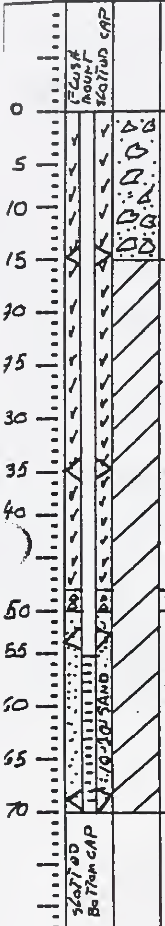
Project TONGUE RIVER DAM	Date Drilled STARTED 12-6-95 FINISHED 12-8-95		Hole No. DH-9A
Location DAM CREST-UPSTREAM SIDE		Ground Surface Elevation	
Drilling Contractor DRILLING ENGINEERING INC.	Logged by D.A. FISHBAUGH	Depth to Ground water 82.5 AUGER	
Type of Rig CMG-75	Hole Diameter 8 1/4	Samples MC SPT ST	



DEPTH	CLASSIFICATION	FIELD DESCRIPTION	SAMPLE SPT MC ST	SPT/MC	DRILL MODE	RUN NO.	REC.	RQD	REMARKS
		PIEZOMETER DH-9A 100' SCREEN 100-95', BENTONITE 80-78' 10-20 SAND 100-80' NEAT CEMENT 78'-SURFACE		MECH. HAMMER 140LBS					18" EPOXY COATED SHELBY TUBES EACH MC CONTAINED 3 - 6" BRASS TUBES
0–15		GP, POORLY GRADED GRAVEL; DRY, DENSE, RED, LARGE SANDSTONE COBBLES > 24" SHELL TOP OF CORE		18" ST EPOXY COATED 3 BRASS TUBES 6" LONG MC					
19		CL, LEAN CLAY; MOIST, STIFF, BROWN	MC 19' 3 TUBES 6" 6" 4"	22	← Hollow STEM AUGER → 4 1/4 ID 8 1/4 OD		16"		MC 19' 7,19,12
29		CL, LEAN CLAY w/GRAVEL; MOIST, STIFF, BROWN	ST 29' 18" REC				18"		
39		CL, LEAN CLAY w/GRAVEL; MOIST, STIFF, BROWN	MC 39' 3 TUBES 6" 6" 6"	24			18"		MC 39' 8, 12, 12
49		CL, LEAN CLAY w/GRAVEL; MOIST, STIFF, BROWN	ST 49' 18" REC				18"		
59		CL, LEAN CLAY; MOIST, STIFF, BROWN	MC 59' 3 TUBES 6" 6" 2.5"	31			14.5"		MC 59' 9,16,15
69		CL, LEAN CLAY w/GRAVEL; MOIST, STIFF, BROWN	ST 69' 18" REC				18"		
79			MC 79'	37			6"		MC 79' 15,22
82		CL, LEAN CLAY w/GRAVEL; MOIST, STIFF, BROWN	SPT 82'	25			18"		SPT 82' 8,12,13
85			MC 85'	23			18"		MC 85' 9,14
87.5		END OF CORE 87.5'							
88		ALLUVIUM | LUF SPT 88': 3" LEAN CLAY 3" GRAVELLY, SANDY CLAY 10" SANDY CLAY 6" GRAVELLY SANDY CLAY WET, SOFT, BROWNISH GRAY	SPT 88'	15			18"		SPT 88' 4,5,10
91		MC 91': 8" LEAN CLAY, CL 10" SILTY SAND, SM WET, SOFT, BROWN	MC 91'	9			0"		MC 91' 4, 5,4
94		SPT 94': 17" SILTY, SANDY LEAN CLAY 3" LEAN CLAY 4" CLAYEY SAND WET, SOFT, GRAYISH BROWN	SPT 94'	15			18"		SPT 94' 5, 5,10
97		MC 97' NO REC.	MC 97'	45			0"		MC 97' 9,17,28
100		SPT 100': 12" SILTY SAND w/CLAY 12" LEAN CLAY w/SILT & SAND WET, SOFT GRAYISH BROWN	SPT 100'	18			18"		SPT 100' 5,7,9
		INTERBEDDED LAYERS LEAN CLAY " " w/ SAND " " w/GRAVEL & SAND SAND w/ SILT & CLAY WET, SOFT, GRAYISH BROWN CL/SP							DEVELOPED WELL BY SURGING & BAILING & PUMPING AIR INTO THE WELL

Terracon

Project TONGUE RIVER DAM	Date Drilled STARTED 12-5-95 FINISHED	Hole No. DH 9B
Location DAM CREST UPSTREAM SIDE	Ground Surface Elevation	
Drilling Contractor DRILLING ENGINEERING INC	Logged by D.A. FISHBAUGH	Depth to Ground water DRY HOLE
pe of Rig CME-75	Hole Diameter 8 1/4"	Samples AUGER SAMPLES ONLY

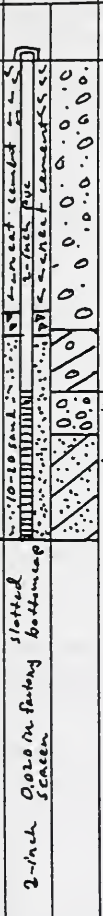


DEPTH	CLASSIFICATION	FIELD DESCRIPTION	SAMPLE	SPT	DRILL MODE	RUN NO.	CORE REC. %	RQD	REMARKS
		DH-9 70' PIEZOMETER FLUSH MOUNT W/ PAD LOCKING CAP	NO SAMPLING - USING AUGER CUTTINGS		Hollow stem Auger 8 1/4 OD 4 1/4 ID.				
0		GP, POORLY GRADED GRAVEL: DRY, DENSE, RED, ANGULAR CLAST OF SANDSTONE & CLINKER, DAM SHELL							
15		CL, LEAN CLAY; DRY-MOIST, STIFF, BROWN, CORE MATERIAL NEAT CEMENT BENTONITE PELLETS 10-20 SILICA SAND							
70		0.02 FACTORY SLOTTED SCREEN 2" SCHEDULE 40 PVC SCREEN 70-55' SOLID RISER 55 - SURFACE < > CENTRALIZERS 69', 54', 35', 15' BOTTOM CAP SLOTTED FOR DRAIN ADDED WATER TO SETTLE SAND & DEVELOPE W/SURGE BLOCK & BAILER							

COREDRIL.DOC

Terracon

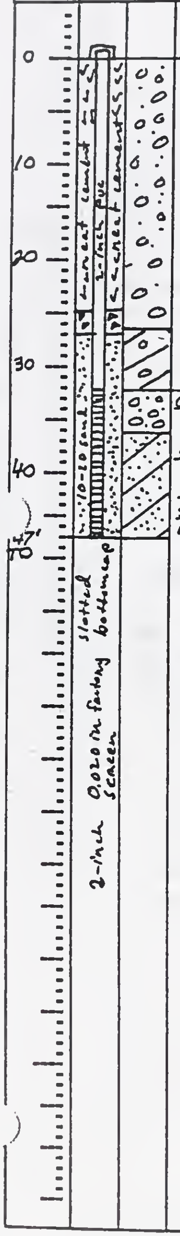
Project TONGUE RIVER DAM	Date Drilled STARTED 12-15-95 FINISHED 12-16-95		Hole No. DH-14
Location LOWER BERM RIGHT ABUTMENT		Ground Surface Elevation	
Drilling Contractor DRILLING ENGINEERING INC	Logged by D.A. FISHBAUGH + D. NOBLE	Depth to Ground water 32'	
Type of Rig CME 75	Hole Diameter 8 1/4	Samples SPT -MC	



DEPTH	CLASSIFICATION	FIELD DESCRIPTION	SAMPLE	SPT	DRILL MODE	RUN NO.	REC. %	RQD	REMARKS
0		GP POORLY GRADED GRAVEL W/SAND, DRY, DENSE, RED SS, SH, + CLINKER CLAST							
10			SPT 9'	4	Hollow stem AUGER		8"		SPT 9' 2, 2, 2
			MC 14'	18			11.5"		MC 14' 3, 12, 6 6" BOT 5.5" MID
20			SPT 19'	4			7"		SPT 19' 4, 1, 3
			MC 24'	59			0		MC 24' 12, 30, 25 BAG SAMPLED
30		CL LEAN CLAY W/GRAVEL MOIST, SOFT, BROWN ALLUVIUM	SPT 29'	11			18"		SPT 29' 3, 3, 8 TORVANE 1.5
		GP POORLY GRADED GRAVEL W/SAND: WET, DENSE, BROWN	MC 34'	66			17"		MC 34' 12, 24, 22 6" BOT 6" MID
40		CL LEAN CLAY W/SAND: WET, SOFT, BROWN, COAL FRAGMENTS.	SPT 39'	13			18"		SPT 39' 4, 5, 8
		INTERBEDDED WITH SP POORLY GRADED SAND W/CLAY WET, SOFT, BROWN	MC 44'	20			12"		MC 44' 5, 8, 12 6" BOT 6" MID
									2-inch 0.020 slot screen sch. 40 pvc 32'-47'

Terracon

Project TONGUE RIVER DAM	Date Drilled STARTED 12-15-95 FINISHED 12-16-95	Hole No. DH-14
Location LOWER BERM RIGHT ABUTMENT	Ground Surface Elevation	
Drilling Contractor DRILLING ENGINEERING INC	Logged by D.A. FISHBAUGH + D. NOBEL	Depth to Ground water 32'
Type of Rig CMG 75	Hole Diameter 8 1/4	Samples SPT -MC



FIELD DESCRIPTION	SAMPLE	SPT	DRILL MODE	RUN NO.	REC. %	RQD	REMARKS
GP POORLY GRADED GRAVEL w/SAND, DRY, DENSE, RED SS, SH, + CLINKER CLAST	SPT 9'	4	Hollow stem AUGER		8"		SPT 9' 2, 2, 2
	MC 14'	18			11.5"		MC 14' 3, 12, 6 6" BOT 5.5" MID
	SPT 19'	4			7"		SPT 19' 4, 1, 3
	MC 24'	59			0		MC 24' 12, 30, 25 BAG SAMPLE
CL LEAN CLAY w/GRAVEL MOIST, SOFT, BROWN	SPT 29'	11			18"		SPT 29' 3, 3, 8 TORVANE 1.5
ALLUVIUM GP POORLY GRADED GRAVEL w/SAND: WET, DENSE, BROWN	MC 34'	66			17"		MC 34' 12, 24, 22 6" BOT 6" MID
CL LEAN CLAY w/SAND: WET, SOFT, BROWN, COAL FRAGMENTS. INTERBEDDED WITH	SPT 39'	13			18"		SPT 39' 4, 5, 8
SP POORLY GRADED SAND w/CLAY WET, SOFT, BROWN	MC 44'	20			12"		MC 44' 5, 8, 12 6" BOT 6" MID
							2-inch 0.020 slot screen sch. 40 pvc 32'-47'

LSA CONSULTANTS
2637 Midpoint Drive, Suite F
Fort Collins, Colorado 80525
(303) 484-3611

Soil and Bedrock Log

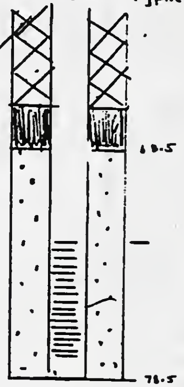
PROJECT Tongue River Dam DATE DRILLED 6/6/98 HOLE NO. #10
LOCATION 100' East of H9 GROUND ELEV. 3448
DRILLING CONTRACTOR Haz Tech LOGGED BY P.S. Plumley DEPTH TO GROUND WATER
TYPE OF RIG Haz-Tech HOLE DIAMETER 8¼" HAMMER WEIGHT AND FALL
SURFACE CONDITIONS Dam Crest TOTAL DEPTH 78.5 NO. CORE BOXES 5

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	SPT (6")	DRILL MODE	RUN NO.	CORE REC. %	REMARKS
5	CLINKER FILL	0 – 9 Reddish brown rock fill w/ sand, silt + clay 65% rk loose, dry			DC	1	40	Start hollow stem auger + continuous sampling @ 12 PM (DC) 5 12:10
3440 10					DC	2	25	10 12:14
15		9 – Medium brown silty clay [CL] stiff, moist w/ 5% rock fragments to ½".			DC	3	100	15 12:17
3430 20	CL				DC	4	100	20 12:24
25	FILL	Becomes slightly darker			DC	5	100	Smooth, easy drilling 25 12:30
3420 30	CL				DC	6	100	30 12:37
35	ML	20% rock fragments Light gray brown clayey silt [ML] stiff, moist; sand is very fine-grained.			DC	7	100	35 12:44
3410 40	FILL	Contact appears near horiz.			DC	7	100	12:50 Drilling resistance increases
45	SILTST	Light yellow brown siltst. closely fractured friable locally grades into silty sand / sandy silt.; poorly cemented	Box 1		DC	8	100	1:00 2:00 Stop augering at 1 PM, switch over to R.W CORE
3400			Box 2		C	1	84	2:05 No Returns
50	S.S.	48.6 – 49.5 Light yell brown sandst, v. poorly cemented silty, weak, friable			C	2		

SHEET 1 OF 2

ROJECT Tongue River Dam DATE DRILLED 6/6/98 HOLE NO. H10

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	WATER TESTS	DRILL MODE	RUN NO.	CORE REC. %	REMARKS
50	SILT-ST	49.5 - 57.2 Yellowish brown siltst w/ leaf fossils along lamination planes, little fractured, low hardness to weak	Box 2	1.7 GPM	C	2	100	52.5 2:35
55		Become carbonaceous at 55.5-57.2			C	3	100	56.0 WATER TEST #1 47 - 56' Head maintained @ +2' above surf. Take - 1.7 GPM
3390	COAL	57.2 -	Box 3		C	4	100	57.5 WATER TEST #2 56 - 67.5 Head maintained @ +2' above surf. Take = 0.2 gpm
60		Black coal, closely fractured, mod hard, weak, with blocky structure Fractures 1 to 2 per inch (or 10-20 per ft) Fractures are near horiz. along bedding planes.		0.2 gpm	C	5	95	62.5 4:15
65 3380			Box 4		C	6	100	67.5 5:10
70				0.7 gpm	C	7	95	72.5 5:30
75 3370	SILT	Light to medium gray Siltstone/MUDST. closely to mod. fractured, low hardness, weak w/ carbon along some lamina planes	Box 5		C	8	100	77.5
					C	9	100	78.5
80		TD @ 78.5						1.5" Screen 77.5 - 72.5 1.5" Blank 72.5 - +2' Sand 78.5 - 68.5 Bentonite Seal 68.5 - 66.5 Grout Seal 66.5 - 0 Set protection COVER
85								
90								Water Test #3 67.5 - 78.5 Head maintained @ +3' above surf Take = 0.7 gpm
95								
50								
100								



SHEET 2 OF 2

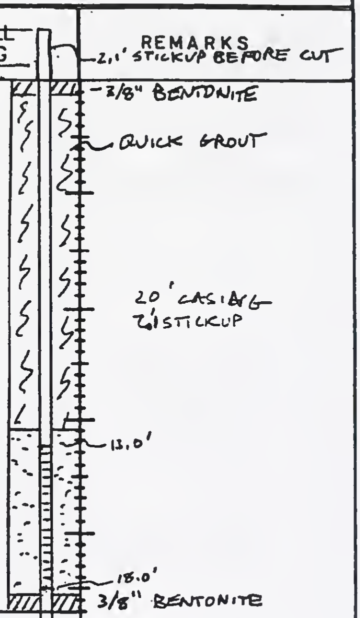
BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-WD2

PROJECT: TONGUE RIVER DAM
PAGE: 1/1
PROJECT NO.: 141.9501
DATE: 6 MAY 99
CLIENT: MDNRC
LOCATION: WEST ABUTMENT
DATE DRILLED: 6 MAY 99
DATE COMPLETED: 6 MAY 99
SURFACE ELEVATION: 3442.87
BORING DEPTH (FT): 18.8'
WELL DEPTH (FT): 18.0'
BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. DRY 24-HOURS: DRY
COMPLETION:
CASING: DIA. (IN) 2 LENGTH (FT): 15' TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 2 LENGTH (FT): 5' SLOT SIZE (IN): .010 DEPTH (FT): 13.0'-18.0'
DRILLING COMPANY: O'KEEFE
DRILLING METHOD: 8" H.S. AUGER, MOBILE B-61
DRILLER: DAVE CROWLEY
DATUM:
LOGGED BY: ACT/ESA
CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
		ORIGINAL 3445.05 0.99 CUT FINAL 3444.06		
2.0				
4.0				
6.0				
8.0				
10.0				
12.0				
14.0				
16.0				
18.0				
		BOH @ 18.8'		
20.0				



SHEET ____ OF ____

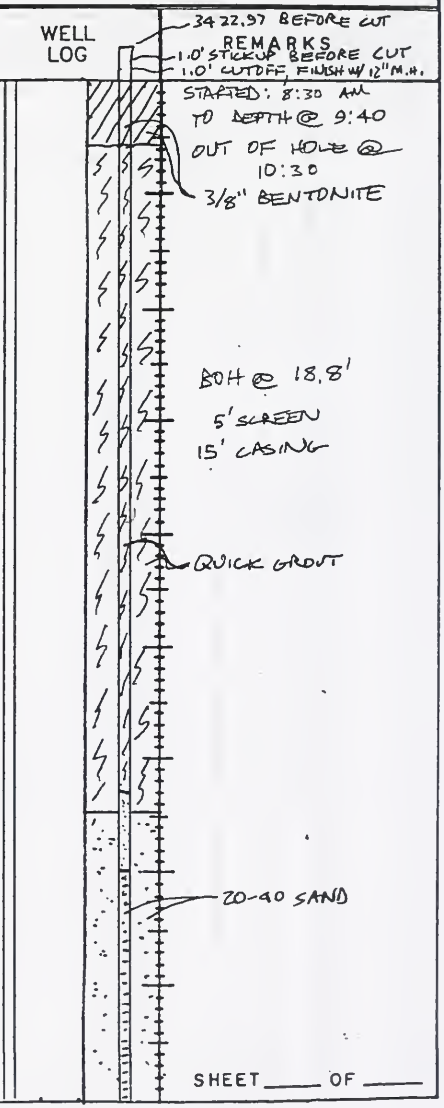
BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-WD1

PROJECT: TONGUE RIVER DAM
PAGE: 1/2
PROJECT NO.: 141.9501
DATE: 5 MAY 99
CLIENT: MDNRC
LOCATION:
DATE DRILLED: 5 MAY 99
DATE COMPLETED: 5 MAY 99
SURFACE ELEVATION: 3421.61
BORING DEPTH (FT): 18.8
WELL DEPTH (FT):
BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT.
24-HOURS:
COMPLETION:
CASING: DIA. (IN) 2
LENGTH (FT): 15'
TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 2
LENGTH (FT): 5'
SLOT SIZE (IN): .010
DEPTH (FT):
DRILLING COMPANY: O'KEEFE
DRILLING METHOD: 8" H.S. AUGER/MOB B-61
DRILLER: DAVE CROWLEY
DATUM:
LOGGED BY: ACT/ESA
CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
1.0				STARTED: 8:30 AM TO DEPTH @ 9:40 OUT OF HOLE @ 10:30
2.0				3/8" BENTONITE
3.0				
4.0				
5.0				BOH @ 18.8'
6.0				5' SCREEN 15' CASING
7.0				
8.0				
9.0				QUICK GROUT
10.0				
11.0				
12.0				
13.0				
14.0				
15.0				20-40 SAND
16.0				
17.0				
18.0				



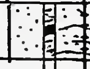
SHEET ____ OF ____

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-WD1

PROJECT: PAGE: 2/2
PROJECT NO.: DATE:
CLIENT:
LOCATION:
DATE DRILLED: DATE COMPLETED: SURFACE ELEVATION:
BORING DEPTH (FT): WELL DEPTH (FT): BOREHOLE DIA. (FT):
WATER LEVEL (FT): INIT. 24-HOURS: COMPLETION:
CASING: DIA. (IN) LENGTH (FT): TYPE:
SCREEN: DIA. (IN) LENGTH (FT): SLOT SIZE (IN): DEPTH (FT):
DRILLING COMPANY: DRILLING METHOD:
DRILLER: DATUM:
LOGGED BY: CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
				VIB WIRE PIEZ @ 18.5' 20-40 SAND
19.0		BOH @ 18.8'		

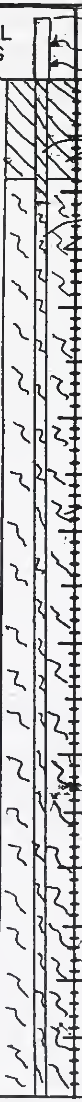
SHEET ____ OF ____

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-SA2

PROJECT: TONGUE RIVER DAM PAGE: 1/3
PROJECT NO.: 141. 9501 DATE: 4 MAY 99
CLIENT: MDNRC
LOCATION: NEAR SW CORNER PRIMARY SPILLWAY (SEE DRAWING)
DATE DRILLED: 4 MAY 99 DATE COMPLETED: 4 MAY 99 SURFACE ELEVATION: 3414.61
BORING DEPTH (FT): 30.5 WELL DEPTH (FT): 7 BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. ____ 24-HOURS: ____ COMPLETION: ____
CASING: DIA. (IN) 2 LENGTH (FT): 25' TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 2 LENGTH (FT): 5' SLOT SIZE (IN): .010 DEPTH (FT): 22.0'-27.0'
DRILLING COMPANY: OKEEFE DRILLING DRILLING METHOD: 8" H.S. AUGER MOB B-61
DRILLER: DAVE CROWLEY DATUM: ____
LOGGED BY: ACJ/ESA CHECKED BY: ____



3417.09 (BEFORE CUT)
3.2' STICKUP PRIOR TO CUTOFF
2.6 CUTOFF, FINISH W/12" MANHOLE

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
		FILL, CLAY		COMPLETED HOLE 3:15AM STARTED HOLE 12:15 AM
1				3/8" BENTONITE
2.0				QUICK GROUT
3.0				
4.0				
5.0				
6.0				
7.0				
8.0				2 BAGS QUICK GROUT
9.0				
10.0				
11.0				
12.0				
13.0				
14.0				
15.0				
16.0				
17.0				

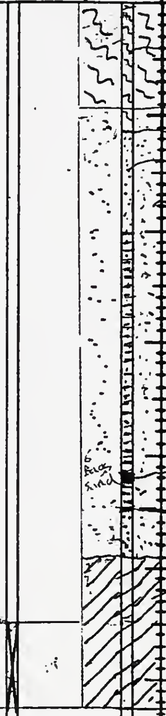
SHEET ____ OF ____

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-SA 2

PROJECT:
PAGE:
PROJECT NO.:
DATE:
CLIENT:
LOCATION:
DATE DRILLED:
DATE COMPLETED:
SURFACE ELEVATION:
BORING DEPTH (FT):
WELL DEPTH (FT):
BOREHOLE DIA. (FT):
WATER LEVEL (FT): INIT.
24-HOURS:
COMPLETION:
CASING: DIA. (IN)
LENGTH (FT):
TYPE:
SCREEN: DIA. (IN)
LENGTH (FT):
SLOT SIZE (IN):
DEPTH (FT):
DRILLING COMPANY:
DRILLING METHOD:
DRILLER:
DATUM:
LOGGED BY:
CHECKED BY:

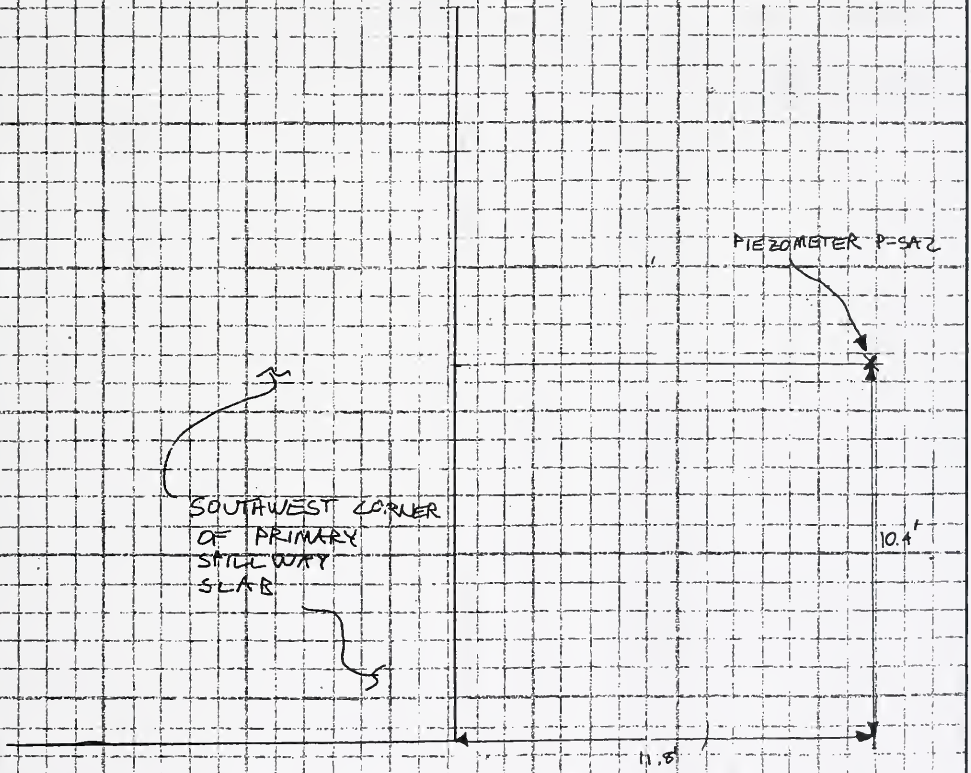
DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
				[illegible]
19.0				QUICK GROUT
20.0				19.9 20.3
21.0				20-40 SAND 6 BAGS 20-40 SAND
22.0				
23.0				
24.0				
25.0				
26.0				[EL 3388.21] 26.4' - SET VIBRATING WIRE PIEZOMETER
27.0				27.0' BOC
28.0				27.8 1 BAG BENTONITE 3/8" CHIPS
29.0		FILL, CLAY, STIFF - V. STIFF 90% REC		
30.0		BEDROCK, ? CLINKER WITH CLAY SILTSTONE BOTTOM OF HOLE @ 30.5		
31.0				

SHEET ____ OF ____

ESA Consultants

JOB NO. 141 SUBJECT P-SA2 PIEZOMETER SHEET NO. 1 OF

PROJECT TONGUE RIVER DAM INSTALLATION BY ACG DATE 6 MAY 99

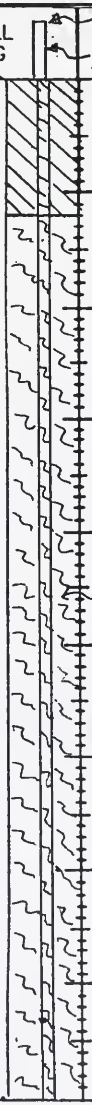


BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-SA1

PROJECT: TONGVE RIVER DAM PAGE: 1/3
PROJECT NO.: 141 9501 DATE: 4 MAY 99
CLIENT: MDNRC
LOCATION: NEAR SW CORNER PRIMARY SPILLWAY (SEE DRAWING)
DATE DRILLED: 4 MAY 99 DATE COMPLETED: 4 MAY 99 SURFACE ELEVATION: 3413.66
BORING DEPTH (FT): 29.3 WELL DEPTH (FT): 27.2 BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. ____ 24-HOURS: ____ COMPLETION: ____
CASING: DIA. (IN) 2 LENGTH (FT): 25' TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 2 LENGTH (FT): 5' SLOT SIZE (IN): .010 DEPTH (FT): 22.2'-27.2'
DRILLING COMPANY: O'KEEFE DRILLING METHOD: MOBILE B-61 8" H.S. AUGER
DRILLER: DAVE CROWLEY DATUM: ____
LOGGED BY: ACJ /ESA CHECKED BY: ____

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
		FILL, CLAY		3416.82 BEFORE CUT 2.9' STICKUP PRIOR TO CUTOFF 2.9' CUTOFF, FINISH W/12" DIAM M.H. BEGIN HOLE 3:15 PM COMPLETE 5:30 1 BAG BENT
1.0				
2.0				
3.0				
4.0				
5.0				
6.0				
7.0				
8.0				
9.0				2 BAGS QUICK GROUT
10.0				
11.0				
12.0				
13.0				
14.0				
15.0				
16.0				
17.0				
18.0				

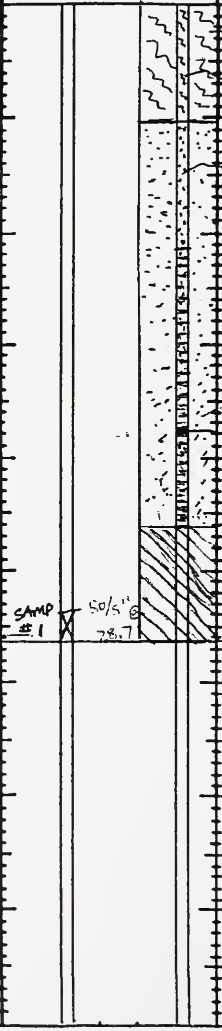
SHEET ____ OF ____

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-SA1

PROJECT: ______ PAGE: 2/3
PROJECT NO.: ______ DATE: ______
CLIENT: ______
LOCATION: ______
DATE DRILLED: ______ DATE COMPLETED: ______ SURFACE ELEVATION: ______
BORING DEPTH (FT): ______ WELL DEPTH (FT): ______ BOREHOLE DIA. (FT): ______
WATER LEVEL (FT): INIT. ______ 24-HOURS: ______ COMPLETION: ______
CASING: DIA. (IN) ______ LENGTH (FT): ______ TYPE: ______
SCREEN: DIA. (IN) ______ LENGTH (FT): ______ SLOT SIZE (IN): ______ DEPTH (FT): ______
DRILLING COMPANY: ______ DRILLING METHOD: ______
DRILLER: ______ DATUM: ______
LOGGED BY: ______ CHECKED BY: ______



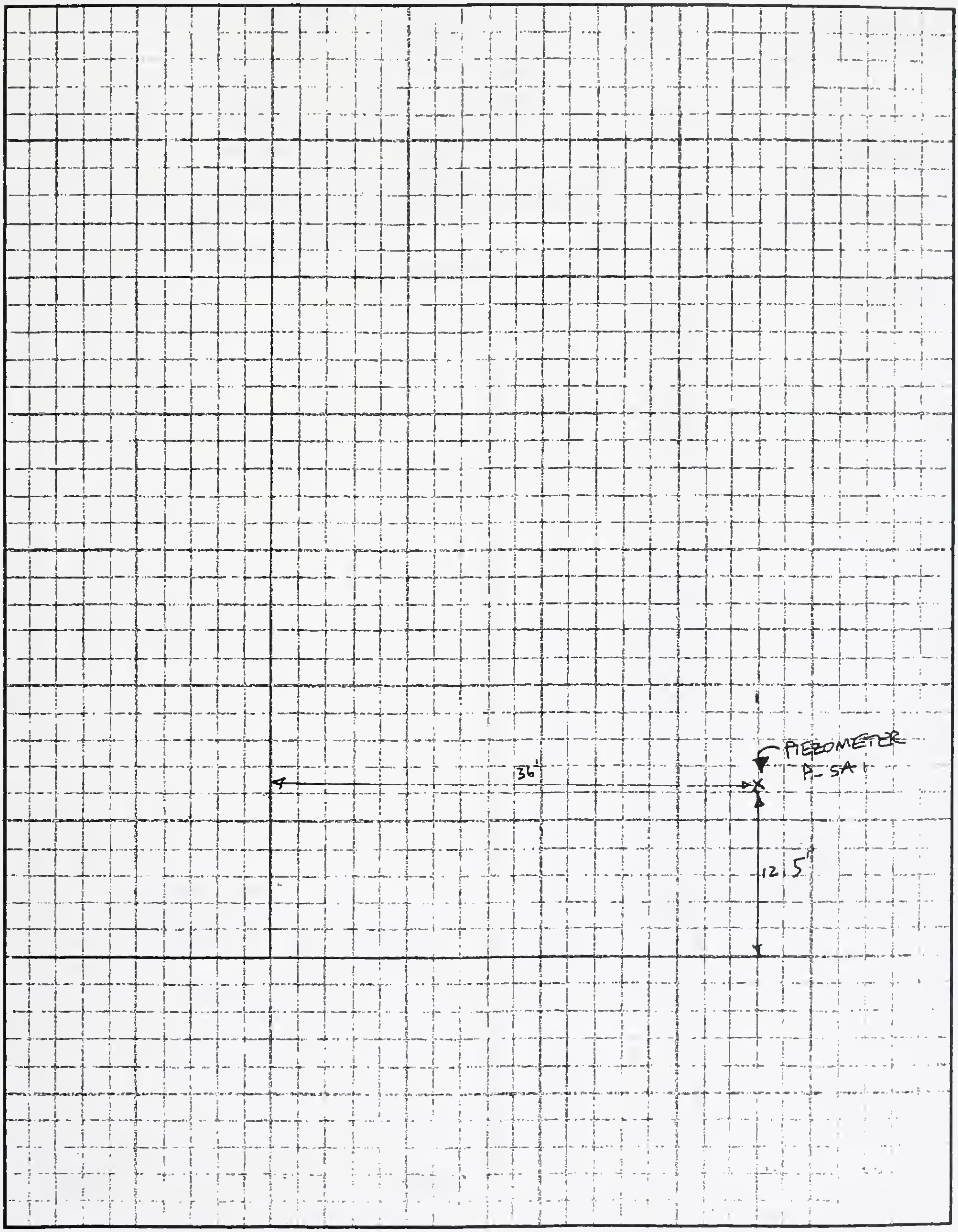
DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
				2 BAGS QUICK GROUT
19.0				QUICK GROUT
20.0				TOP OF SAND @ 20'
21.0				SAND 20x40
22.0				
23.0				
24.0				
25.0				6 BAGS 20 x 40 SAND
26.0				VIBRATING WIRE PIEZOMETER AT 25.6' [EL 3391.06]
27.0				27.2' BOC BENTONITE 1 BAG
28.0				
29.0		BOH @ 29.3	SAMP #1 50/5" @ 28.7	4:15
30.0				NOTE: VIB WIRE PIEZ NOT ON SITE AT TIME OF DRILLING. SET CASING FOR LATER INSERTION
31.0				
32.0				

SHEET ______ OF ______

ESA Consultants

JOB NO. ____ SUBJECT P-SA1 LOCATION SHEET NO. 2 OF 3

PROJECT ____ BY ____ DATE ____



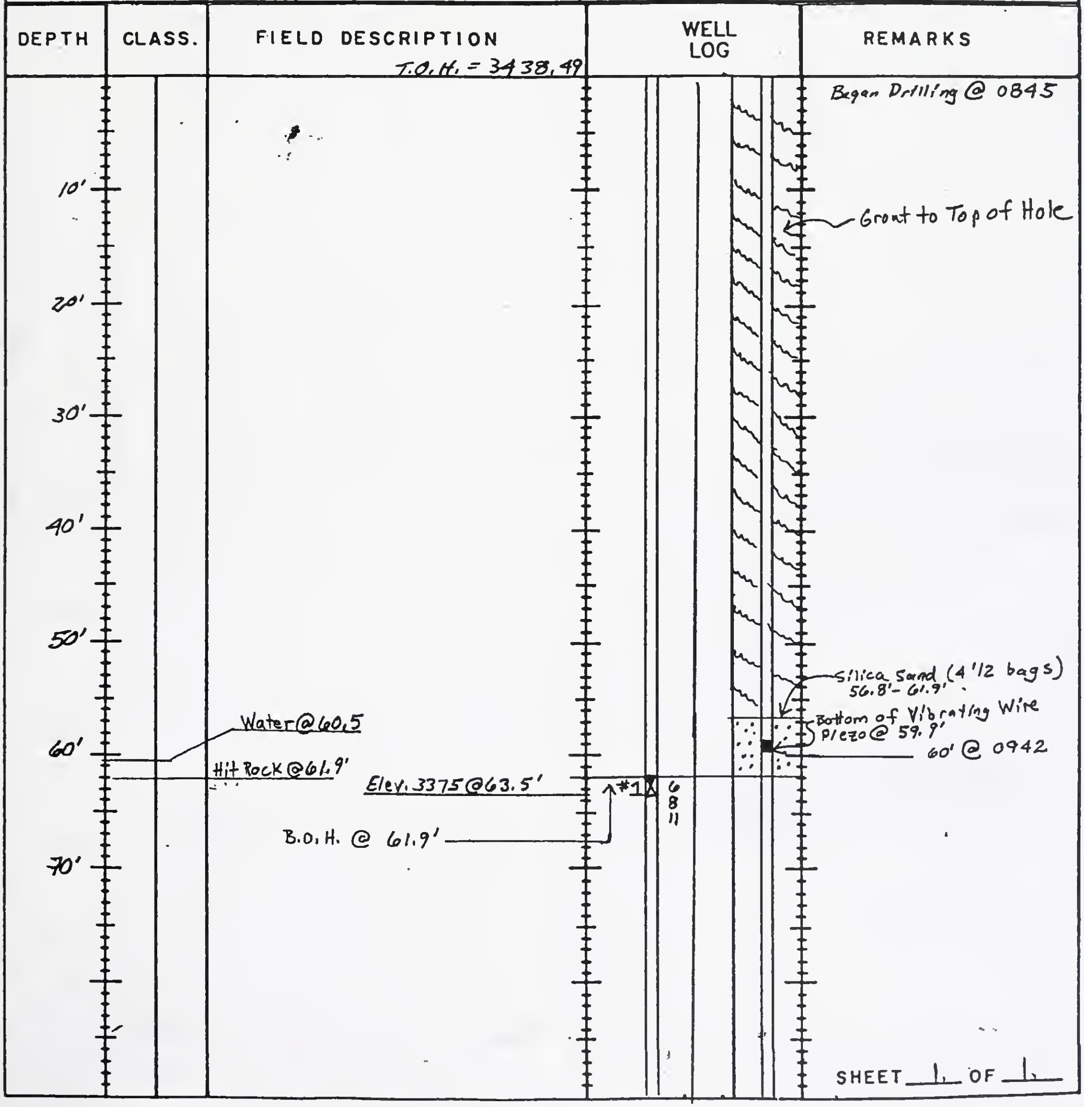
BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-US2

PROJECT: Tongue River Dam, Phase III PAGE: 1
PROJECT NO.: 141.9501 DATE: 5-17-99
CLIENT: DNRC
LOCATION: D/S of sheetpile Cutoff, on U/S slope bet. Spillways
DATE DRILLED: 5-17-99 DATE COMPLETED: 5-17-99 SURFACE ELEVATION: 3438.49
BORING DEPTH (FT): 61.9' WELL DEPTH (FT): 59.9' BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. 24-HOURS: COMPLETION:
CASING: DIA. (IN) N/A LENGTH (FT): TYPE:
SCREEN: DIA. (IN) N/A LENGTH (FT): SLOT SIZE (IN): DEPTH (FT):
DRILLING COMPANY: O'Keefe Drilling DRILLING METHOD: 8" Hollow Stem Auger
DRILLER: Dave Crowley DATUM: Mobile B61
LOGGED BY: Steve Story CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS



SHEET 1 OF 1

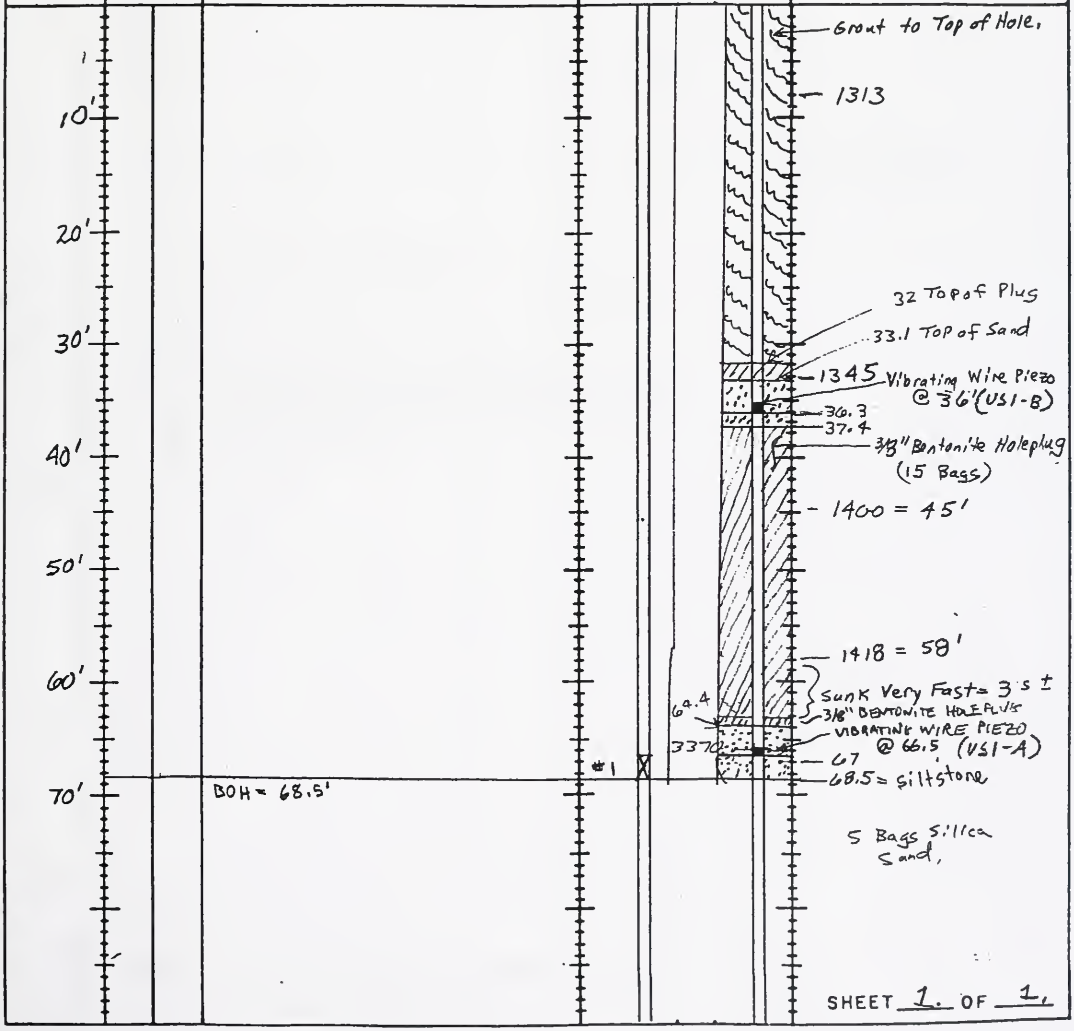
BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO.
P-USI (A) and
P-USI (B)

PROJECT: Tongue River Dam, Phase III
PAGE: 1
PROJECT NO.: 141.9301
DATE: 5-14-99
CLIENT: DNRC
LOCATION: Upstream Slope bet. Service & Emer. Spillways, U/S Sheetpile 10+25
DATE DRILLED: 5-14-99
DATE COMPLETED: 5-14-99
SURFACE ELEVATION: 3436.08
BORING DEPTH (FT): 68.5'
WELL DEPTH (FT): 66.5'
BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT.
24-HOURS:
COMPLETION:
CASING: DIA. (IN) N/A
LENGTH (FT):
TYPE:
SCREEN: DIA. (IN) N/A
LENGTH (FT):
SLOT SIZE (IN):
DEPTH (FT):
DRILLING COMPANY: O'Keefe Drilling
DRILLING METHOD: 8" Hollow Stem Auger. Mobile B61
DRILLER: Dave Crowley
DATUM:
LOGGED BY: Steve Story
CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS

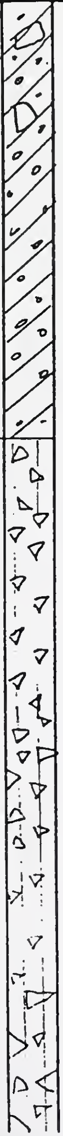


SHEET 1. OF 1.

ESA CONSULTANTS
2637 Midpoint Drive, Suite F
Fort Collins, Colorado 80525
(303) 484-3611

Soil and Bedrock Log

PROJECT Tongue River Dam DATE DRILLED 1/7/99 HOLE NO. AH-3
LOCATION 81' from wing wall end N 30 E GROUND ELEV. ~3442.1
DRILLING CONTRACTOR Interstate LOGGED BY P.S Plumley DEPTH TO GROUND WATER None
TYPE OF RIG CME 750 HOLE DIAMETER 8¼" HAMMER WEIGHT AND FALL 140 lbs/30"
SURFACE CONDITIONS Rough graded TOTAL DEPTH 75.5 NO. CORE BOXES



DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	SPT (6")	DRILL MODE	RUN NO.	CORE REC. %	REMARKS
		medium gray GRAVELLY CLAY CL w/ Frags of rock (siltst) to sev. inches or more, Firm, moist						
5	CL			6 5 5				
10				4 7 7				- Stop 1/7/99 start 1/8/99 5° F
15		Fragments of siltst, clinker, coal clayst. to > 2"	BAG	13 13 16				
20	GM/GC	Brownish red silty gravel (GM/GC) [CLINKER FILL], Frags of brick red baked siltst. in a sandy silt matrix	BAG	12 8 6				slow, hard drilling
25				30 46 40				
30				29 35 36				← Advancement w/ [illegible] augers [illegible]
35		Fill Sample [illegible] Fragmented [illegible] w/ [illegible]		10 18 20				
40				26 23 26				
45		Fill [illegible] dark red/ mottled, mix of both w/ a weathered clasts	BAG	12 16 20				

SHEET 1 OF 2

PROJECT Tongue River Dam DATE DRILLED 1/7 + 1/8/99 HOLE NO. AH-3

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	SPT (6")	DRILL MODE	RUN NO.	CORE REC %	REMARKS
55	(GM) FILL	GRAVELLY SILT / SILTY GRAVEL (GM), brownish red, very stiff, slightly moist. contains coarse sand to 1.5 gravel size frags of both well rounded + angular clasts, Also, altered (Baked) + unbaked	BAG	20 19 21				Texture suggest mat. is Fill!
	ML/SM (FILL)	SANDY SILT (ML), med.-dk gray, very stiff. dry to moist, w/ occas carbon frags.	BAG	14 23 35				
60	?	Dk red. brown, Fragments of Fused clinker + carbon [clinker?]						Drilling resistance increases.
		SANDST - hard, mod st, Fragment...	BAI	29 92 44				Poor sample recov.
65	CLINKER	Brick, orange-red, BAKED SILTST, intens frac, low hard, friable w/ calcium carb. along fractures	BAG	20 43 10				
				6 4 1				Likely void ~ 6" at 68'
70		Light grey clay [ASH], soft, wet, low density Ash @ base of clinker						Void ~ 6" @ top of drive rods drop.
	CLAY ST	Mottled grey + brown CLAY ST, discolored fm heat but not disrupted. Becomes silty	BAG	4 2 14				
				100/5"				Redrilled hole w/ larger 8½" o.d. augers; meas bottom after completion 70.5

Completed boring as piezometer:
IN CLINKER
PLUG 70.5 - 75.5
SILT TRAP 69.5 - 70.5
Screen (0.10) 64.5 - 69.5 (2")
BLANK CASING +2 - 64.5 (2")

BACKFILL MATERIALS.
COARSE SAND 58.0 - 71.5
BENTONITE PELLETS 56.0 - 58.0
BENTONITE GROUT 0.0 - 56.0
STEEL CASING LOCKING COVER

SHEET ___ OF ___

ESA CONSULTANTS
2637 Midpoint Drive, Suite F
Fort Collins, Colorado 80525
(303) 484-3611

Soil and Bedrock Log

PROJECT Tongue River Dam DATE DRILLED 1-13-99 HOLE NO. AH-5 AH-5
LOCATION approx 10 ft N of west end of [illegible] wall GROUND ELEV. [illegible]
DRILLING CONTRACTOR IDS LOGGED BY [illegible] DEPTH TO GROUND WATER
TYPE OF RIG CME 75 AT HOLE DIAMETER 8"/4¼" HAMMER WEIGHT AND FALL 140#/auto hammer/30"
SURFACE CONDITIONS Frozen/muddy gravel TOTAL DEPTH 81 ft NO. CORE BOXES

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	SPT (6")	DRILL MODE	RUN NO.	CORE REC. %	REMARKS
								Begin drilling 12:15
5								
10	CL	9-11 Silty CLAY; dark brown, moist, stiff, low plastic, some fine grained sand, about 5% 1/8"-1/4" gravel, becomes sandy silt from 9.5-10 [Fill]	1355 1500	[illegible]	HSA	1	[illegible]	
15								
20	ML CL	19-21 Clayey silt; reddish brown, moist, stiff, slightly plastic; layer about 1" thick grading to Silty CLAY; dark brown, moist to stiff, low plastic, [illegible] [Fill]	[illegible]	[illegible]	[illegible]	2	[illegible]	
25								
30	CL	29-31 CLAY; dark brown, moist, v. stiff, low to moderately plastic, [illegible], trace fine grained sand, about 5% [illegible] [illegible] gravel [Fill]	[illegible] 1550	[illegible]	HSA	3	[illegible]	
35								
40	CL	39-41 Silty CLAY, dark brown, [illegible] moist v. stiff, low plastic, [illegible] [illegible] [illegible] [illegible] [illegible] stiff, organic clay [illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	
45								
50								

FILL

SHEET 1 OF —

Jan 14 99 09:07A LSA 406 757 2458 P.04

PROJECT [illegible] DATE DRILLED [illegible]-98 HOLE NO. AH-5

AH-5

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	SPT	DRILL MODE	RUN NO	CORE REC %	REMARKS
50	CL	49-51 Silty CLAY, dark brown, moist, v. stiff, low to med plastic, massive, trace f.-c. grnd sand, about 2% gravel to ¾" [FILL]	2"SS 1445	10 9 14 20	HSA	5	100	
55								
60	CL	59-61 Silty CLAY, dark brown, moist, v. stiff, low to med. plastic, massive, trace f.-c. grnd sand, some ½" gravel [illegible] [FILL]	2"SS 1520	10 12 16 23	HSA	6	100	
65	ML Coal	64-64.8 Clayey SILT, dark brown, moist, stiff, some f.-c. grnd sand, small coal fragments						
	CL	64.8-66 Silty CLAY, dark brown, moist, stiff to v. stiff, massive [FILL]	2"SS 1540	3 10 7 9	HSA	7	95	
70	CL- ML?	69-71 Clayey SILT to silty CLAY, dark brown, moist, v. stiff, slightly plastic, massive, some f.-c. grnd sand, about 2-5% [illegible] to coal, & clinker & [illegible] gravel ¼" to 1" [FILL]	2"SS 1505	11 13 15 16	HSA	8	95	Sample [illegible]
75	ML- CL	74-74.1 Silty CLAY (as above) [FILL] 74.1-76.1 Clayey SILT w/ some f.-c. grnd sand, light brown, moist, stiff, massive, no gravel, lower contact at [illegible] [Alluvium]	2"SS 1030	5 6 7 12	HSA	9	100	Sample AH [illegible] Sample AH [illegible]
	SLST	76.1-76 SILTSTONE; tan to olive brown, moist, v. weak, friable, highly weathered, 1" thick carbonaceous layer in shoe	2"SS 1050	3 5 7 8	HSA	10	100	
80		76-78 SILTSTONE/CLAYSTONE; tan to light brown, moist, extremely weak, friable, highly weathered, laminated w/ carbonaceous layers near base	2"SS 1710	10 12 8 14	HSA	11	90	
	TD 81'	78-81 SILTSTONE; light brown grading to light gray, moist, laminated, weak, friable to low hardness, iron brown mottling [illegible]						1145 [illegible]

324.3

32?.?

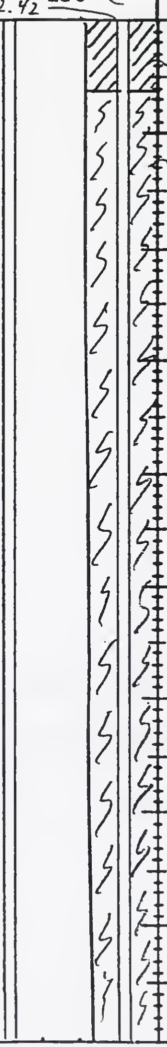
SHEET ____ OF ____

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO.
P-CL1

PROJECT: TONGUE RIVER DAM, PAGE: 1/2
PROJECT NO.: 141.9501 DATE: 7 MAY 99
CLIENT: MDNRC
LOCATION: TONGUE RIVER DAM CREST, U/S EDGE, ~60' WEST OF W. EDGE OF E. SPILLWAY
DATE DRILLED: 7 MAY 99 DATE COMPLETED: 7 MAY 99 SURFACE ELEVATION:
BORING DEPTH (FT): 75.0' WELL DEPTH (FT): 72.6' BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. 24-HOURS: COMPLETION:
CASING: DIA. (IN) 2 LENGTH (FT): 70' TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 2 LENGTH (FT): 5 SLOT SIZE (IN): .010 DEPTH (FT): 67.6'-72.6
DRILLING COMPANY: OKEEFE DRILLING METHOD: 8" H.S AUGER/MOBILE B-61
DRILLER: DAVE CROWLEY DATUM:
LOGGED BY: ACT CHECKED BY:



DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
		FILL - SANDY SILTY GRAVEL, TYPE		START DRILLING 9:30 AM
		CLINKER FILL - SILTY SANDY GRAVEL, COBBLES, DRY, dense		3/8" BENTONITE
5.0				
		CLAY CORE - SILTY CLAY(CL), moist, some sand,		QUICK GROUT
10.0				
15.0				
20.0				10:15AM
25.0				
30.0				
35.0				
40.0				
45.0				

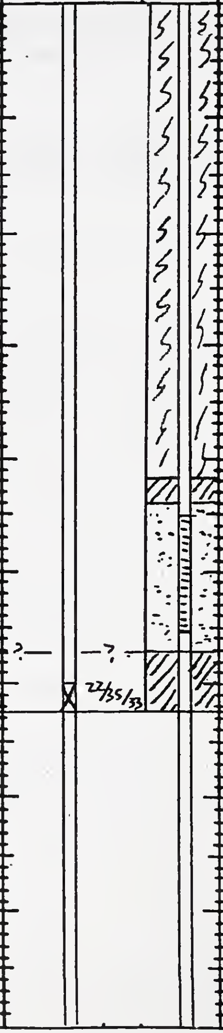
SHEET 1 OF 2

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-CL1

PROJECT:
PAGE: 2/2
PROJECT NO.:
DATE:
CLIENT:
LOCATION:
DATE DRILLED: DATE COMPLETED: SURFACE ELEVATION:
BORING DEPTH (FT): WELL DEPTH (FT): BOREHOLE DIA. (FT):
WATER LEVEL (FT): INIT. 24-HOURS: COMPLETION:
CASING: DIA. (IN) LENGTH (FT): TYPE:
SCREEN: DIA. (IN) LENGTH (FT): SLOT SIZE (IN): DEPTH (FT):
DRILLING COMPANY: DRILLING METHOD:
DRILLER: DATUM:
LOGGED BY: CHECKED BY:



DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
				QUICK GROUT
50.0				
55.0				
60.0				DRILLER SHUTS DOWN RIG@12:30 PM TO CHANGE CABLE FOR TOOL - NOT LONG ENOUGH
65.0				3/8" BENTONITE
				20-40 SAND
70.0				
	? ?	SILTSTONE, GREY, MOIST, WEATHERED	22/35/33	3/8" BENTONITE
75.0				
		BOH @ 76.5' @ 3:45 PM		
80.0				

SHEET ____ OF ____

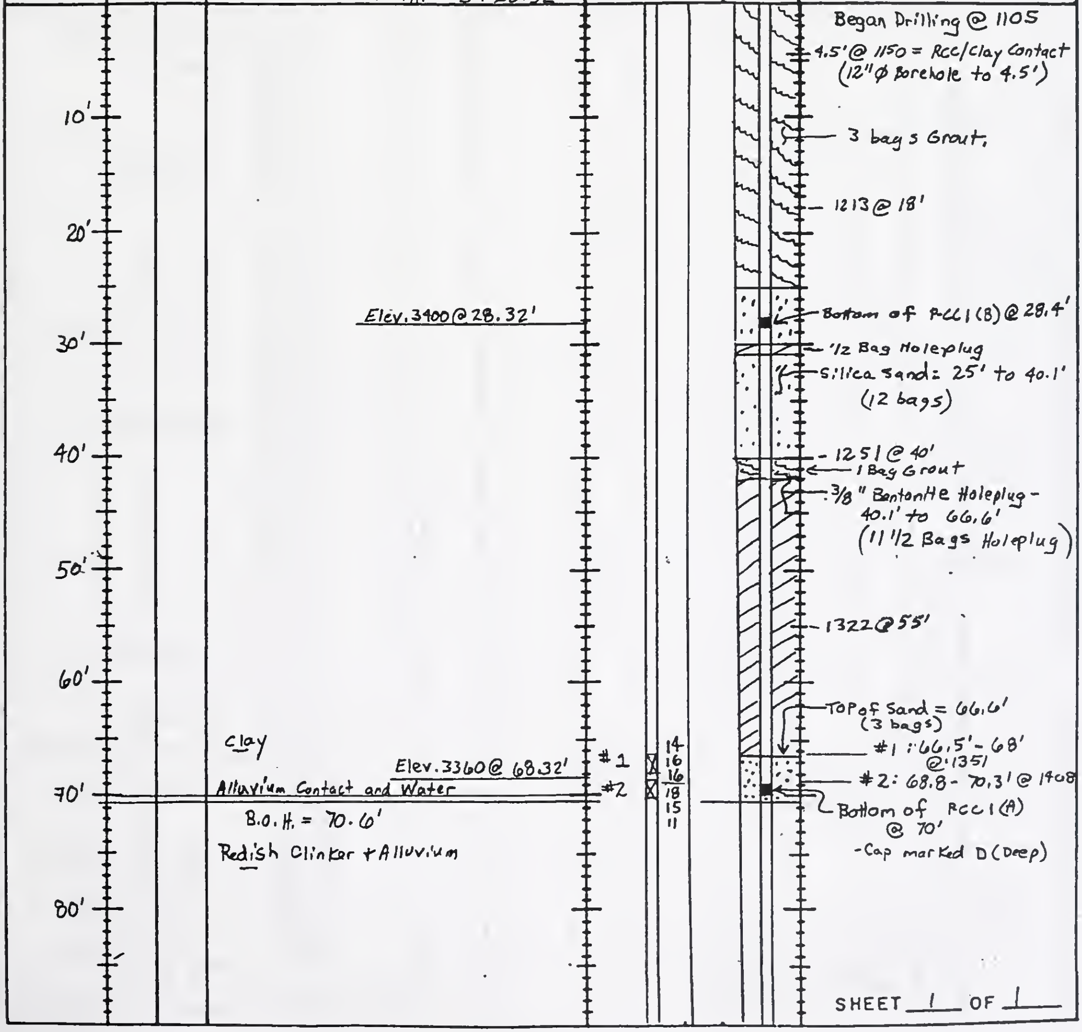
BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO.
P-CC1 (A) and
P-CC1 (B)

PROJECT: Tongue River Dam, Phase III
PAGE: 1
PROJECT NO.: 141.9501
DATE: 5-16-99
CLIENT: DNRC
LOCATION: Upstream edge dam crest / center (Thru. Emer. Splll. RCC Apron).
DATE DRILLED: 5-16-99 DATE COMPLETED: 5-16-99 SURFACE ELEVATION: 3428.32
BORING DEPTH (FT): 70.6' WELL DEPTH (FT): 70' BOREHOLE DIA. (FT): 12" to 5', then 8"
WATER LEVEL (FT): INIT. ____ 24-HOURS: ____ COMPLETION: ____
CASING: DIA. (IN) ____ LENGTH (FT): ____ TYPE: ____
SCREEN: DIA. (IN) ____ LENGTH (FT): ____ SLOT SIZE (IN): ____ DEPTH (FT): ____
DRILLING COMPANY: O'Keefe Drilling DRILLING METHOD: 8" Hollow Stem Auger
DRILLER: Dave Crowley DATUM: Mobile B61
LOGGED BY: Steve Story CHECKED BY: ____

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS



T.O.H. = 3428.32

Elev. 3400 @ 28.32'

Clay

Elev. 3360 @ 68.32'

Alluvium Contact and Water

B.O.H. = 70.6'

Redish Clinker + Alluvium

Began Drilling @ 1105

4.5' @ 1150 = RCC/Clay Contact (12"ϕ Borehole to 4.5')

3 bags Grout.

1213 @ 18'

Bottom of P-CC1 (B) @ 28.4'

1/2 Bag Holeplug

Silica sand: 25' to 40.1' (12 bags)

1251 @ 40'

1 Bag Grout

3/8" Bentonite Holeplug - 40.1' to 66.6' (11 1/2 Bags Holeplug)

1322 @ 55'

TOP of Sand = 66.6' (3 bags)

#1: 66.5' - 68' @ 1351

#2: 68.8 - 70.3' @ 1408

Bottom of PCC1 (A) @ 70'
-Cap marked D (Deep)

SHEET 1 OF 1

BORING/WELL COMPLETION LOG

ESA Consultants

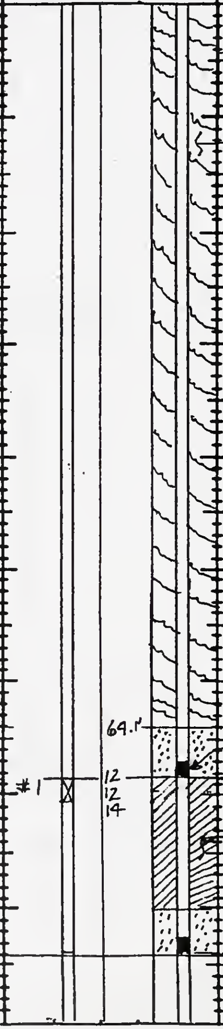
BORING/WELL NO.
P-CC2(A) and
P-CC2(B)

PROJECT: Tongue River Dam, Phase III PAGE: 1
PROJECT NO.: 141, 9501 DATE: 5-15-99
CLIENT: DNRC
LOCATION: Downstream Edge dam Crest/Center (Thru. Emer. Spill. RCC Apron)
DATE DRILLED: 5-15-99 DATE COMPLETED: 5-16-99 SURFACE ELEVATION: 3428.67
BORING DEPTH (FT): 84.1' WELL DEPTH (FT): 83.9' BOREHOLE DIA. (FT): 12" to 5" then
WATER LEVEL (FT): INIT. ____ 24-HOURS: ____ COMPLETION: ____
CASING: DIA. (IN) ____ LENGTH (FT): ____ TYPE: ____
SCREEN: DIA. (IN) ____ LENGTH (FT): ____ SLOT SIZE (IN): ____ DEPTH (FT): ____
DRILLING COMPANY: O'Keefe Drilling DRILLING METHOD: 8" Hollow Stem Auger
DRILLER: Dave Crowley DATUM: Mobile B61
LOGGED BY: Steve Story CHECKED BY: ____

DEPTH | CLASS. | FIELD DESCRIPTION | WELL LOG | REMARKS

FIELD DESCRIPTION: T.o.H. = 3428.67

DEPTH: 10' 20' 30' 40' 50' 60' 70' 80'



Clay ?? Elev = 3359.77
Alluvium

84.1' = B.O.H.

REMARKS:
4.5' Bottom of RCC
0930 @ 5'
Grouted 5-16-99 in AM.
1055 @ 38'
1200 @ 58'
1215 @ 63'
Bottom of PCC2(A) @ 68.9
1245 Sample 1
TOP @ 68.9'
3/8" Bentonite Holeplug (68.9' to 80.1') (3 bags)
80.1' Top of sand. (2½ bags)
Bottom of P-CC2(B) @ 83.9

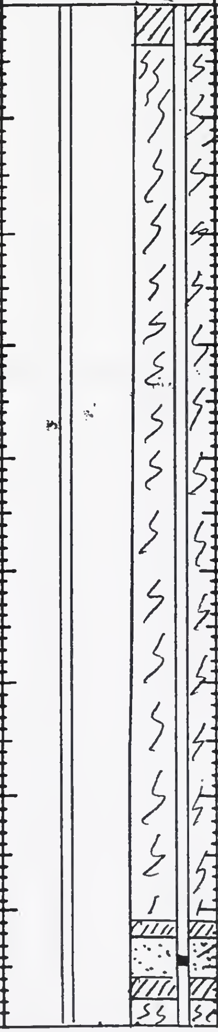
SHEET 1 OF 1.

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO.
P-CRZ A/B

PROJECT: TONGUE RIVER DAM
PAGE: 1/2
PROJECT NO.: 141.9501
DATE: 11 MAY 99
CLIENT: MDNRC
LOCATION: EAST OF EMERGENCY SPILLWAY
DATE DRILLED: 10 MAY 99
DATE COMPLETED: 11 MAY 99
SURFACE ELEVATION:
BORING DEPTH (FT): 132'
WELL DEPTH (FT): 130'
BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT.
24-HOURS:
COMPLETION:
CASING: DIA. (IN) 1/1
LENGTH (FT): 130/85'
TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 1/1
LENGTH (FT): 1'/1'
SLOT SIZE (IN): .010
DEPTH (FT):
DRILLING COMPANY: O'KEEFE
DRILLING METHOD: 8" H.S AUGER/ MOB B-61
DRILLER: DAVE CROWLEY
DATUM:
LOGGED BY: ACJ/ESA
CHECKED BY:



DEPTH	CLASS.	FIELD DESCRIPTION	A-3443.21 B-3443.15 WELL LOG	REMARKS
				~3/8" BENTONITE WATER @ 88'
10.0				QUICK GROUT
20.0				
30.0				
40.0				
50.0				
60.0				
70.0				
80.0				3/8" BENTONITE P-CRZ(A) 1" FILTER TIP SET @ 84.0' - 85.0' 3/8" BENTONITE
90.0		WATER ENCOUNTERED DURING DRILLING @ 88.0'		QUICK GROUT

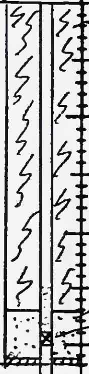
SHEET ____ OF ____

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-CRZ A/B

PROJECT: ______ PAGE: 2/2
PROJECT NO.: ______ DATE: ______
CLIENT: ______
LOCATION: ______
DATE DRILLED: ______ DATE COMPLETED: ______ SURFACE ELEVATION: ______
BORING DEPTH (FT): ______ WELL DEPTH (FT): ______ BOREHOLE DIA. (FT): ______
WATER LEVEL (FT): INIT. ______ 24-HOURS: ______ COMPLETION: ______
CASING: DIA. (IN) ______ LENGTH (FT): ______ TYPE: ______
SCREEN: DIA. (IN) ______ LENGTH (FT): ______ SLOT SIZE (IN): ______ DEPTH (FT): ______
DRILLING COMPANY: ______ DRILLING METHOD: ______
DRILLER: ______ DATUM: ______
LOGGED BY: ______ CHECKED BY: ______

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
90.0				QUICK GROUT
100.0				
120.0				20-40 SAND P-CRZ (B) 1" DIAM FILTER TIP SET @ 129.0'-130.0'
130.0				3/8" BENTONITE
		BOH @ 132.0'		
140.0				

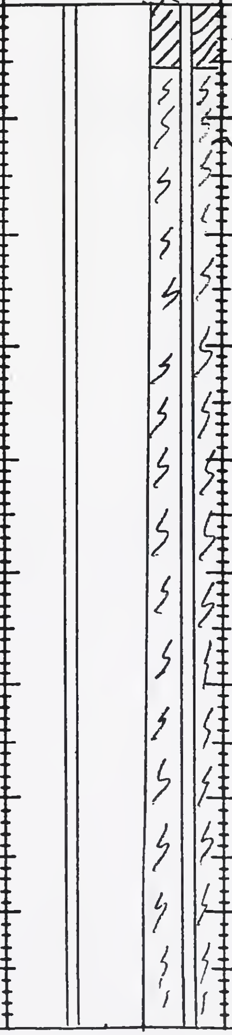
SHEET ______ OF ______

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-CR2(C)

PROJECT: TONGUE RIVER DAM PAGE: 1/2
PROJECT NO.: 191.9501 DATE: 13 MAY 99
CLIENT: MDNRC
LOCATION: EAST OF EMERGENCY SPILLWAY
DATE DRILLED: 13 MAY99 DATE COMPLETED: 14 MAY99 SURFACE ELEVATION:
BORING DEPTH (FT): 98.7 WELL DEPTH (FT): 98.2 BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. ___ 24-HOURS: ___ COMPLETION:
CASING: DIA. (IN) 2 LENGTH (FT): ~~95~~ 95' TYPE:
SCREEN: DIA. (IN) 2 LENGTH (FT): 5' SLOT SIZE (IN): .010 DEPTH (FT): 93.2-98.2
DRILLING COMPANY: O'KEEFE DRILLING METHOD: 8" H.S. AUGER/MOB B-61
DRILLER: DAVE CROWLEY DATUM:
LOGGED BY: AGT/ESA CHECKED BY:

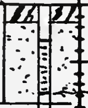
DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
			3442.97 	3/8" BENTONITE
10.0				QUICK GROUT
20.0				
30.0				
40.0				
50.0				
60.0				
70.0				
80.0				
90.0				SHEET ___ OF ___

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-CR2(C)

PROJECT: PAGE: 2/2
PROJECT NO.: DATE:
CLIENT:
LOCATION:
DATE DRILLED: DATE COMPLETED: SURFACE ELEVATION:
BORING DEPTH (FT): WELL DEPTH (FT): BOREHOLE DIA. (FT):
WATER LEVEL (FT): INIT. 24-HOURS: COMPLETION:
CASING: DIA. (IN) LENGTH (FT): TYPE:
SCREEN: DIA. (IN) LENGTH (FT): SLOT SIZE (IN): DEPTH (FT):
DRILLING COMPANY: DRILLING METHOD:
DRILLER: DATUM:
LOGGED BY: CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION	WELL LOG	REMARKS
				3/8" BENTONITE 20-40 SAND 98.2
100		BOH @ 98.7'		
110				

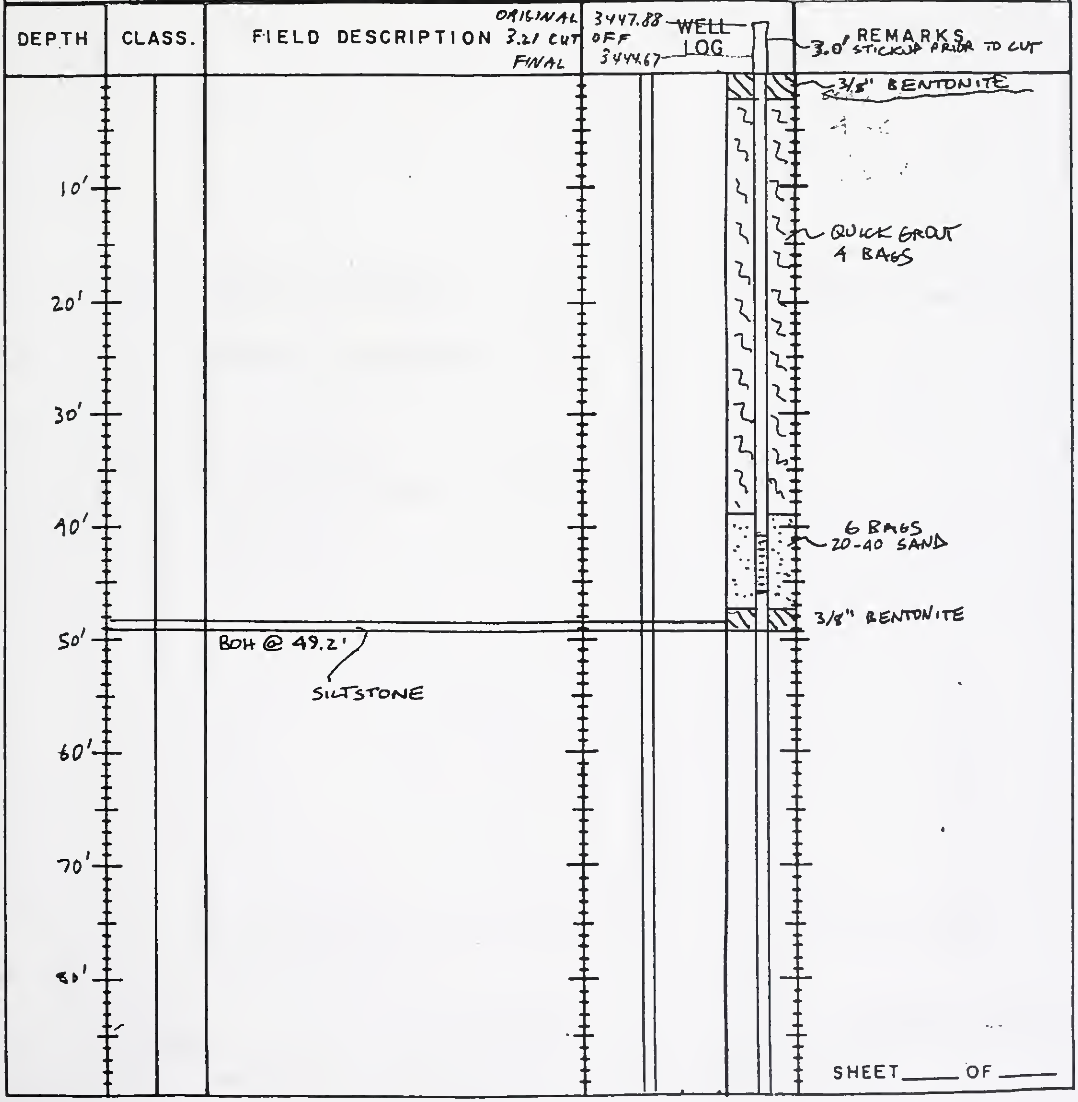
SHEET ____ OF ____

BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-CR1

PROJECT: TONGUE RIVER DAM PAGE: 1/1
PROJECT NO.: 141.9501 DATE: 5 MAY 99
CLIENT: MDNRC
LOCATION: EAST ABUTMENT
DATE DRILLED: 5 MAY 99 DATE COMPLETED: 5 MAY 99 SURFACE ELEVATION:
BORING DEPTH (FT): 49.2' WELL DEPTH (FT): 46.0' BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. DRY 24-HOURS: COMPLETION:
CASING: DIA. (IN) 2 LENGTH (FT): 45' TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 2 LENGTH (FT): 5' SLOT SIZE (IN): .010 DEPTH (FT): 41.0'-46.0'
DRILLING COMPANY: O'KEEFE DRILLING METHOD: 8" H.S. AUGER, MOB B-61
DRILLER: DAVE CROWLEY DATUM:
LOGGED BY: ACJ/ESA CHECKED BY:



SHEET ____ OF ____

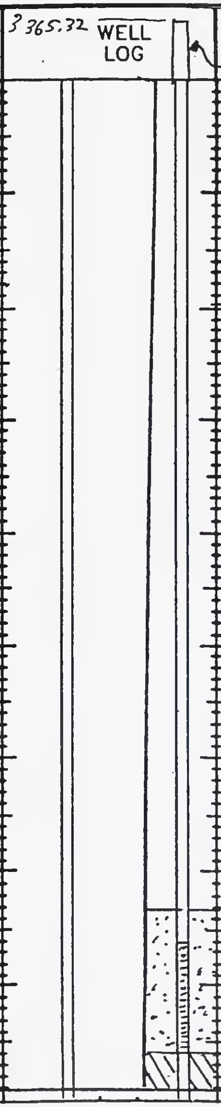
BORING/WELL COMPLETION LOG

ESA Consultants

BORING/WELL NO. P-DR2

PROJECT: TONGUE RIVER DAM
PAGE: 1/1
PROJECT NO.: 141.9501
DATE: 6 MAY 99
CLIENT: MDNRC
LOCATION: VALLEY BOTTOM DOWNSTREAM R. OF DAM, E. OF E. SPILL TAILRACE
DATE DRILLED: 6 MAY 99
DATE COMPLETED: 6 MAY 99
SURFACE ELEVATION:
BORING DEPTH (FT): 44.5
WELL DEPTH (FT): 43.1
BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT.
24-HOURS:
COMPLETION: 38.1'-43.1'
CASING: DIA. (IN) 2"
LENGTH (FT): 40'
TYPE: PVC TRI-LOC
SCREEN: DIA. (IN) 2"
LENGTH (FT): 5'
SLOT SIZE (IN): .010
DEPTH (FT): 38.1'-43.1'
DRILLING COMPANY: O'KEEFE
DRILLING METHOD: 8" H.S. AUGER, MOB B-61
DRILLER: DAVE CROWLEY
DATUM:
LOGGED BY: ACJ/ESA
CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION	REMARKS
		FILL	1.7' STICKUP
5.0			
10		ALLUVIUM - SILT, black,	▽ 7 MAY 99 @ 4:15 PM
		ALLUVIUM - SANDY GRAVEL	
15			
		ALLUVIUM - SILTY SAND	
20			
25			
30			
35			
			6 BAGS 20-40 SAND
		ALLUVIUM, GRAVEL	
40			
			COMPLETED HOLE @ 3:45 PM
			BENTONITE
45		BOH @ 44.5	



44.55
10.95

SHEET ____ OF ____

BORING/WELL COMPLETION LOG

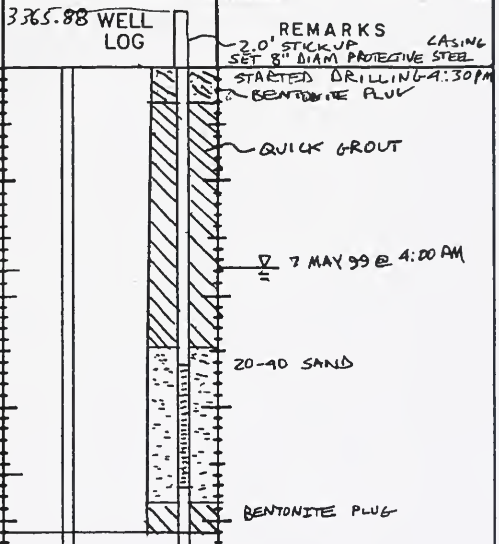
ESA Consultants

BORING/WELL NO. P-DR1.

PROJECT: TONGUE RIVER DAM
PAGE: 1/1
PROJECT NO.: 141.9501
DATE: 6 MAY 99
CLIENT: MDNRC
LOCATION: EMERGENCY SPILLWAY TAILRACE CHANNEL (EAST OF)
DATE DRILLED: 6 MAY 99
DATE COMPLETED: 6 MAY 99
SURFACE ELEVATION:
BORING DEPTH (FT): 20.5
WELL DEPTH (FT): -18.4
BOREHOLE DIA. (FT): 8"
WATER LEVEL (FT): INIT. ______ 24-HOURS: ______ COMPLETION: ______
CASING: DIA. (IN) 2 LENGTH (FT): 15.0 TYPE: PVC, 5' SLOTTED SCREEN
SCREEN: DIA. (IN) 2 LENGTH (FT): 5.0 SLOT SIZE (IN): .010 DEPTH (FT): 13.4'-18.4'
DRILLING COMPANY: O'KEEFE
DRILLING METHOD: 8" H.S. AUGER, MOB B-61
DRILLER: DAVE CRONLEY
DATUM:
LOGGED BY: ALJ/ESA
CHECKED BY:

DEPTH	CLASS.	FIELD DESCRIPTION
		FILL
5.0		
		ALLUVIUM - SILT, BLACK
10.0		
		ALLUVIUM - SANDY GRAVEL
15		
		ALLUVIUM - SILTY SAND
20		
		BOH @ 20.5'
25		

3365.88 WELL LOG



REMARKS

2.0' STICKUP
SET 8" DIAM PROTECTIVE STEEL CASING
STARTED DRILLING 4:30PM
BENTONITE PLUG
QUICK GROUT
7 MAY 99 @ 4:00 AM
20-40 SAND
BENTONITE PLUG

SHEET ____ OF ____

APPENDIX G

VIBRATING WIRE AND DATA LOGGER INFORMATION

TABLE 9. TONGUE RIVER DAM VIBRATING WIRE WELLS

New Name	Old Name	Year Drilled	Type		Total Depth	Standpipe Wells		Vibrating Wires	
			(sp)	(vw)	(ft)	Depth (ft)	TOP Elev (ft)	Depth (ft)	Reference Elev (ft)
209A	DH-9(A)	1995	sp	vw	100	100	3443.10	98.1	3443.10
209B	DH-9(B)	1995	sp	vw	70	70	3443.20	48.9	3443.20
310	H-10	1998	sp	vw	78.5	77.5	3450.90	80.3	3450.90
401	P-WD2	1999	sp	vw	18.8	18.0	3444.10	19.01	3444.10
402	P-WD1	1999		vw	18.8			19.55	3422.97
403	P-SA2	1999		vw	30.5			28.98	3417.09
404	P-SA1	1999		vw	29.3			28.5	3416.82
405	P-US2	1999		vw	61.9			59.9	3438.49
406A	P-US1(A)	1999		vw	68.5			66.5	3436.08
406B	P-US1(B)	1999		vw	68.5			36	3436.08
407	AH-3	1999	sp	vw	75.5	71.0	3443.30	74.3	3443.30
408	AH-5	1999	sp	vw	81	80.0	3440.80	78	3440.80
409	P-CL1	1999	sp	vw	75	72.6	3442.40	72.38	3442.40
412A	P-CR2(A)	1999	sp	vw	132	85.0	3443.20	84.5	3443.20
412B	P-CR2(B)	1999	sp	vw	132	130.0	3443.20	130	3443.20
412C	P-CR2(C)	1999	sp	vw	98.7	98.2	3443.00	99.3	3443.00
413	P-CR1	1999	sp	vw	49.2	46.0	3444.70	45.7	3444.70

Vibrating Wire Depth = depth below reference elevation

Number of monitoring wells (vibrating wire piezometers only)	6
Number of monitoring wells (vibrating wire and standpipe)	11
Total Vibrating Wire Piezometers	17

ROCTEST

Instrumentation
Géotechnique et Structurale

DH-209A

CALIBRATION DATA SHEET

VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99173**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**150 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3172.8	1767.5	-0.13
10.00	3003.8	1719.8	-0.01
20.00	2834.1	1670.5	0.04
30.00	2663.9	1619.6	0.02
40.00	2493.7	1567.0	0.00
50.00	2322.7	1512.3	-0.10
50.00	2322.7	1512.3	-0.10
40.00	2494.1	1567.1	0.05
30.00	2664.5	1619.7	0.10
20.00	2835.0	1670.8	0.14
10.00	3004.6	1720.0	0.09
0.00	3173.1	1767.6	-0.10
		Max error %:	0.14

Calibration factor: CF = **-5.880E-02 psi / LU**
CK = **-5.971E-05 psi / Hz^2**
Temperature factor: CT = **-0.01614 psi / °F**

Calculated pressure:

$$P\ (\text{psi}) = CF\ (L_1 - L_0) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

$$P\ (\text{psi}) = CK\ (F_1^2 - F_0^2) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu
Date: 05/26/99

ROCTEST
Instrumentation
Géotechnique et Structurale

DH-209B

CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99175**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**120 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3309.5	1805.2	-0.12
10.00	3124.8	1754.1	-0.02
20.00	2939.9	1701.4	0.07
30.00	2754.1	1646.8	0.06
40.00	2568.0	1590.1	0.01
50.00	2381.0	1531.2	-0.13
50.00	2381.1	1531.2	-0.11
40.00	2568.3	1590.2	0.04
30.00	2754.7	1646.9	0.13
20.00	2940.3	1701.5	0.12
10.00	3125.2	1754.2	0.03
0.00	3309.8	1805.3	-0.09
		Max error %:	0.13

Calibration factor: CF = -5.385E-02 psi / LU
CK = -5.469E-05 psi / Hz^2
Temperature factor: CT = -0.01690 psi / °F

Calculated pressure:

$$P\ (\text{psi}) = CF\,(L_1 - L_0) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

$$P\ (\text{psi}) = CK\,(F_1^2 - F_0^2) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu
Date: 05/26/99

ROCTEST
Instrumentation
Géotechnique et Structurale

DH-310

CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99168**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**600 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3422.2	1835.6	-0.10
10.00	3244.4	1787.3	-0.04
20.00	3066.7	1737.7	0.03
30.00	2888.8	1686.5	0.07
40.00	2710.3	1633.6	0.05
50.00	2530.4	1578.4	-0.12
50.00	2530.4	1578.5	-0.11
40.00	2710.4	1633.6	0.06
30.00	2888.6	1686.5	0.06
20.00	3067.4	1737.9	0.11
10.00	3245.5	1787.6	0.08
0.00	3422.3	1835.7	-0.09
		Max error %:	0.12

Calibration factor: CF = -5.608E-02 psi / LU
CK = -5.695E-05 psi / Hz^2
Temperature factor: CT = -0.01393 psi / °F

Calculated pressure:

$$P\ (\text{psi}) = CF\ (L_1 - L_0) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

$$P\ (\text{psi}) = CK\ (F_1^2 - F_0^2) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu D.J.
Date: 05/26/99

ROCTEST
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Géotechnique et Structurale

DH-401

CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99171**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**190 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3335.4	1812.2	-0.11
10.00	3157.1	1763.1	-0.03
20.00	2979.0	1712.7	0.08
30.00	2799.7	1660.3	0.05
40.00	2620.5	1606.3	0.03
50.00	2440.3	1550.1	-0.10
50.00	2440.4	1550.1	-0.09
40.00	2620.1	1606.2	-0.01
30.00	2799.9	1660.4	0.07
20.00	2979.3	1712.8	0.12
10.00	3158.3	1763.5	0.11
0.00	3335.3	1812.2	-0.12
		Max error %:	0.12

Calibration factor: CF = -5.585E-02 psi / LU
CK = -5.672E-05 psi / Hz^2
Temperature factor: CT = -0.01606 psi / °F

Calculated pressure:

$$P\text{ (psi)} = CF\,(L_1 - L_0) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

$$P\text{ (psi)} = CK\,(F_1^2 - F_0^2) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu

Date: 05/26/99

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DH-402

CALIBRATION DATA SHEET

VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99111
Range:	50 PSI
Temperature:	75.5 °F
Barometric pressure:	29.59 in. Hg
Cable model:	IRC-41A
Cable length:	265.0 ft
Thermistor type:	2 kohms

Color code: red & black (coil) ***green & white (thermistor)***

Applied pressure (psi)	Ascending (L.U.)	Descending (L.U.)	Average (L.U.)	Calculated pressure (psi)	F.S. Error (%)
0.00	2747.1	2746.5	2746.8	0.00	0.00
5.00	2661.4	2661.6	2661.5	5.00	0.01
10.00	2575.8	2575.8	2575.8	10.01	-0.02
15.00	2490.3	2490.5	2490.4	14.99	0.02
20.00	2404.2	2404.4	2404.3	20.01	-0.01
25.00	2318.4	2318.6	2318.5	25.00	0.01
30.00	2231.9	2232.5	2232.2	30.01	-0.01
35.00	2146.0	2146.0	2146.0	35.00	0.00
40.00	2059.4	2059.6	2059.5	40.00	0.01
45.00	1972.7	1972.8	1972.7	45.01	-0.01
50.00	1885.9	1886.2	1886.1	50.00	0.01
				Max. error (%):	0.02

Calibration factors:

C_1 = 5.863E-02 psi / L.U. **T_k= 0.00943 psi / °F rise**

C_2 = -6.305E-07 psi / L.U.²

Pressure is calculated with the following polynomial equation:

$$P\ (\text{psi}) = [C_1\,(L_0 - L_1)] + [C_2\,(L_0 - L_1)^2] - [T_k\,(T_0 - T_1)] + [0.491(B_0 - B_1)]$$

C_1,C_2 = polynomial factors
L_0,L_1 = initial (at installation) and current readings, in L.U.
T_0,T_1 = initial (at installation) and current temperature, in °F
B_0, B_1 = initial (at installation) and current barometric pressure, in inches of Hg
0.491 = constant for all vibrating wire sensors, in psi/in. of Hg
L.U.= Linear Units (with K=1.0156)

NIST traceability no T100B951 Procedure: cp100bra.doc
Filename: 030299d1.xls Revision: 1.0

Calibrated by: Date: 99-05-03

DH-403

ROCTEST Ltd.
Geotechnical and
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CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99113
Range:	50 PSI
Temperature:	75.5 °F
Barometric pressure:	29.59 in. Hg
Cable model:	IRC-41A
Cable length:	290.0 ft
Thermistor type:	2 kohms

Color code: red & black (coil) *green & white (thermistor)*

Applied pressure (psi)	Ascending (L.U.)	Descending (L.U.)	Average (L.U.)	Calculated pressure (psi)	F.S. Error (%)
0.00	2858.7	2858.1	2858.4	0.00	0.00
5.00	2766.3	2766.1	2766.2	5.00	-0.01
10.00	2674.3	2674.0	2674.1	9.99	0.02
15.00	2581.5	2581.8	2581.7	14.99	0.01
20.00	2489.0	2489.0	2489.0	20.00	0.01
25.00	2396.0	2396.3	2396.1	25.00	-0.01
30.00	2303.2	2303.5	2303.3	30.00	0.00
35.00	2209.9	2210.2	2210.0	35.01	-0.02
40.00	2116.9	2117.0	2116.9	40.00	-0.01
45.00	2023.8	2023.6	2023.7	45.00	0.01
50.00	1930.3	1930.0	1930.2	50.00	0.01
				Max. error (%):	0.02

Calibration factors:

$C_1 =$ **5.431E-02 psi / L.U.** $T_k =$ **0.00252 psi / °F rise**

$C_2 =$ **-4.848E-07 psi / L.U.²**

Pressure is calculated with the following polynomial equation:

$$P\ (\text{psi}) = [C_1 (L_0 - L_1)] + [C_2 (L_0 - L_1)^2] - [T_k (T_0 - T_1)] + [0.491 (B_0 - B_1)]$$

C_1, C_2 = polynomial factors
L_0, L_1 = initial (at installation) and current readings, in L.U.
T_0, T_1 = initial (at installation) and current temperature, in °F
B_0, B_1 = initial (at installation) and current barometric pressure, in inches of Hg
0.491 = constant for all vibrating wire sensors, in psi/in. of Hg
L.U.= Linear Units (with K=1.0156)

NIST traceability no T100B951
Filename: 030299d1.xls

Procedure: cp100bra.doc
Revision: 1.0

Calibrated by:

Date: 99-05-03

ROCTEST Ltd.
Geotechnical and
Structural Instrumentation

DH-404

CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99112
Range:	50 PSI
Temperature:	75.5 °F
Barometric pressure:	29.59 in. Hg
Cable model:	IRC-41A
Cable length:	300.0 ft
Thermistor type:	2 kohms

Color code: red & black (coil) ***green & white (thermistor)***

Applied pressure (psi)	Ascending (L.U.)	Descending (L.U.)	Average (L.U.)	Calculated pressure (psi)	F.S. Error (%)
0.00	3467.9	3466.9	3467.4	0.00	0.00
5.00	3376.7	3376.7	3376.7	4.97	0.05
10.00	3285.1	3285.0	3285.0	10.00	0.01
15.00	3193.5	3193.6	3193.6	15.00	0.01
20.00	3101.6	3102.0	3101.8	20.01	-0.01
25.00	3009.8	3010.3	3010.1	25.01	-0.01
30.00	2918.2	2918.5	2918.3	30.00	0.00
35.00	2826.1	2826.2	2826.2	35.01	-0.01
40.00	2733.8	2734.3	2734.1	40.00	0.00
45.00	2641.5	2641.9	2641.7	45.00	0.00
50.00	2549.3	2549.4	2549.3	50.00	0.01
				Max. error (%):	0.05

Calibration factors:

C_1 = 5.491E-02 psi / L.U. **T_k= -0.00323 psi / °F rise**

C_2 = -4.852E-07 psi / L.U.²

Pressure is calculated with the following polynomial equation:

$$P\ (\text{psi}) = [C_1\,(L_0 - L_1)] + [C_2\,(L_0 - L_1)^2] - [T_k\,(T_0 - T_1)] + [0.491(B_0 - B_1)]$$

C_1,C_2 = polynomial factors
L_0,L_1 = initial (at installation) and current readings, in L.U.
T_0,T_1 = initial (at installation) and current temperature, in °F
B_0,B_1 = initial (at installation) and current barometric pressure, in inches of Hg
0.491 = constant for all vibrating wire sensors, in psi/in. of Hg
L.U.= Linear Units (with K=1.0156)

NIST traceability no T100B951
Filename: 030299d1.xls

Procedure: cp100bra.doc
Revision: 1.0

Calibrated by: ______________

Date: 99-05-03

ROCTEST Ltd.
Geotechnical and
Structural Instrumentation

CALIBRATION DATA SHEET

VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99116
Range:	50 PSI
Temperature:	75.5 °F
Barometric pressure:	29.59 in. Hg
Cable model:	IRC-41A
Cable length:	800.0 ft
Thermistor type:	2 kohms

Color code: red & black (coil) *green & white (thermistor)*

Applied pressure (psi)	Ascending (L.U.)	Descending (L.U.)	Average (L.U.)	Calculated pressure (psi)	F.S. Error (%)
0.00	3313.3	3312.6	3312.9	0.00	0.00
5.00	3225.4	3225.1	3225.3	5.00	0.00
10.00	3137.5	3137.6	3137.6	10.00	0.01
15.00	3049.3	3049.6	3049.4	15.00	-0.01
20.00	2961.2	2961.2	2961.2	20.01	-0.03
25.00	2873.3	2873.5	2873.4	24.99	0.02
30.00	2784.7	2784.9	2784.8	30.00	0.00
35.00	2696.1	2696.5	2696.3	35.00	0.00
40.00	2608.0	2607.7	2607.8	39.99	0.02
45.00	2518.8	2518.9	2518.8	45.00	0.00
50.00	2429.7	2429.9	2429.8	50.00	-0.01
				Max. error (%):	0.03

Calibration factors:

$C_1 =$ **5.708E-02 psi / L.U.** $T_k =$ **-0.00300 psi / °F rise**

$C_2 =$ **-5.208E-07 psi / L.U.²**

Pressure is calculated with the following polynomial equation:

$$P\ (\text{psi}) = [C_1 (L_0 - L_1)] + [C_2 (L_0 - L_1)^2] - [T_k (T_0 - T_1)] + [0.491 (B_0 - B_1)]$$

C_1, C_2 = polynomial factors
L_0, L_1 = initial (at installation) and current readings, in L.U.
T_0, T_1 = initial (at installation) and current temperature, in °F
B_0, B_1 = initial (at installation) and current barometric pressure, in inches of Hg
0.491 = constant for all vibrating wire sensors, in psi/in. of Hg
L.U.= Linear Units (with K=1.0156)

NIST traceability no T100B951
Filename: 030299d1.xls
Procedure: cp100bra.doc
Revision: 1.0

Calibrated by: Date: 99-05-03

ROCTEST Ltd.
Geotechnical and
Structural Instrumentation

DH-406A

CALIBRATION DATA SHEET

VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99114
Range:	50 PSI
Temperature:	75.5 °F
Barometric pressure:	29.59 in. Hg
Cable model:	IRC-41A
Cable length:	820.0 ft
Thermistor type:	2 kohms

Color code: red & black (coil) ***green & white (thermistor)***

Applied pressure (psi)	Ascending (L.U.)	Descending (L.U.)	Average (L.U.)	Calculated pressure (psi)	F.S. Error (%)
0.00	2876.3	2875.5	2875.9	0.00	0.00
5.00	2787.2	2786.7	2787.0	5.00	0.00
10.00	2697.8	2697.7	2697.7	10.00	0.00
15.00	2608.6	2608.9	2608.7	14.98	0.04
20.00	2518.8	2518.9	2518.9	20.00	0.00
25.00	2429.1	2429.1	2429.1	25.00	-0.01
30.00	2339.2	2339.3	2339.2	30.00	0.00
35.00	2248.8	2248.9	2248.9	35.01	-0.03
40.00	2158.8	2158.8	2158.8	40.00	0.00
45.00	2068.3	2068.4	2068.3	45.00	0.00
50.00	1977.7	1977.8	1977.8	49.99	0.01
				Max. error (%):	0.04

Calibration factors:

C_1 = 5.625E-02 psi / L.U. **T_k= 0.00660 psi / °F rise**

C_2 = -6.488E-07 psi / L.U.^{2}

Pressure is calculated with the following polynomial equation:

$$P\ (\text{psi}) = [C_1 (L_0 - L_1)] + [C_2 (L_0 - L_1)^2] - [T_k (T_0 - T_1)] + [0.491 (B_0 - B_1)]$$

C_1,C_2 = polynomial factors
L_0,L_1 = initial (at installation) and current readings, in L.U.
T_0,T_1 = initial (at installation) and current temperature, in °F
B_0,B_1 = initial (at installation) and current barometric pressure, in inches of Hg
0.491 = constant for all vibrating wire sensors, in psi/in. of Hg
L.U.= Linear Units (with K=1.0156)

NIST traceability no T100B951
Filename: 030299d1.xls
Procedure: cp100bra.doc
Revision: 1.0

Calibrated by:
Date: 99-05-03

665 Pine Avenue, Saint-Lambert (Quebec) Canada J4P 2P4 Tel. : (450) 465-1113 Fax : (450) 465-1938
E-mail : info@roctest.com • Web Site : http: //www. roctest.com

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DH-406B

CALIBRATION DATA SHEET

VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99115
Range:	50 PSI
Temperature:	75.5 °F
Barometric pressure:	29.59 in. Hg
Cable model:	IRC-41A
Cable length:	790.0 ft
Thermistor type:	2 kohms

Color code: red & black (coil) *green & white (thermistor)*

Applied pressure (psi)	Ascending (L.U.)	Descending (L.U.)	Average (L.U.)	Calculated pressure (psi)	F.S. Error (%)
0.00	3232.3	3231.5	3231.9	0.00	0.00
5.00	3138.4	3138.2	3138.3	5.01	-0.02
10.00	3044.3	3044.8	3044.6	10.02	-0.03
15.00	2951.1	2951.1	2951.1	15.00	-0.01
20.00	2857.1	2857.2	2857.1	20.01	-0.02
25.00	2763.3	2763.4	2763.4	25.00	0.01
30.00	2669.5	2669.4	2669.5	29.98	0.03
35.00	2574.8	2575.2	2575.0	35.00	0.01
40.00	2480.5	2480.7	2480.6	39.99	0.01
45.00	2385.6	2385.9	2385.7	45.01	-0.02
50.00	2291.2	2291.2	2291.2	50.00	0.00
				Max. error (%):	0.03

Calibration factors:

$C_1 =$ **5.354E-02 psi / L.U.** $T_k =$ **0.00116 psi / °F rise**

$C_2 =$ **-4.136E-07 psi / L.U.²**

Pressure is calculated with the following polynomial equation:

$$P\ (\text{psi}) = [C_1 (L_0 - L_1)] + [C_2 (L_0 - L_1)^2] - [T_k (T_0 - T_1)] + [0.491(B_0 - B_1)]$$

C_1, C_2 = polynomial factors
L_0, L_1 = initial (at installation) and current readings, in L.U.
T_0, T_1 = initial (at installation) and current temperature, in °F
B_0, B_1 = initial (at installation) and current barometric pressure, in inches of Hg
0.491 = constant for all vibrating wire sensors, in psi/in. of Hg
L.U.= Linear Units (with K=1.0156)

NIST traceability no T100B951 Procedure: cp100bra.doc
Filename: 030299d1.xls Revision: 1.0

Calibrated by: Date: 99-05-03

DH-407

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CALIBRATION DATA SHEET

VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Seriel number:	**100D99165**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**760 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3370.5	1821.7	-0.10
10.00	3199.0	1774.8	0.01
20.00	3026.8	1726.4	0.05
30.00	2854.4	1676.5	0.05
40.00	2682.2	1625.1	0.09
50.00	2508.2	1571.5	-0.09
50.00	2508.3	1571.5	-0.08
40.00	2681.3	1624.9	-0.01
30.00	2854.3	1676.4	0.04
20.00	3026.9	1726.4	0.06
10.00	3199.0	1774.8	0.01
0.00	3371.0	1821.9	-0.04
		Max error %:	0.10

Calibration factor: CF = **-5.798E-02 psi / LU**
CK = **-5.888E-05** $\mathbf{psi / Hz^2}$
Temperature factor: CT = **-0.01364 psi / °F**

Calculated pressure:

$$P\ (psi) = CF\ (L_1 - L_0) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

$$P\ (psi) = CK\ (F_1^2 - F_0^2) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu S.J.
Date: 05/26/99

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CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99166**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**670 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil)** **green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3344.9	1814.8	-0.11
10.00	3177.2	1768.7	-0.02
20.00	3009.9	1721.5	0.12
30.00	2841.0	1672.5	0.07
40.00	2672.6	1622.2	0.07
50.00	2502.5	1569.7	-0.13
50.00	2502.5	1569.7	-0.13
40.00	2672.5	1622.2	0.05
30.00	2841.1	1672.6	0.07
20.00	3009.6	1721.5	0.08
10.00	3177.5	1768.8	0.01
0.00	3345.1	1814.9	-0.09
		Max error %:	0.13

Calibration factor: **CF =** **-5.936E-02 psi / LU**
CK = **-6.029E-05 psi / Hz²**
Temperature factor: **CT =** **-0.01280 psi / °F**

Calculated pressure:

$$P\ (\text{psi}) = CF\,(L_1 - L_0) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

$$P\ (\text{psi}) = CK\,(F_1^2 - F_0^2) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no:	T100B951	Procedure:	PE100DRC
Filename:	052699A.xls		

Calibrated by: Dorina Jugureanu   Date: 05/26/99

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CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99167**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**710 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3495.5	1855.2	-0.13
10.00	3326.5	1809.8	-0.01
20.00	3157.0	1763.1	0.05
30.00	2987.3	1715.1	0.10
40.00	2816.6	1665.3	0.01
50.00	2645.3	1613.9	-0.13
50.00	2645.4	1613.9	-0.12
40.00	2816.7	1665.4	0.02
30.00	2987.9	1715.2	0.16
20.00	3157.5	1763.2	0.12
10.00	3327.0	1809.9	0.05
0.00	3495.6	1855.2	-0.11
		Max error %:	0.16

Calibration factor: CF = -5.881E-02 psi / LU
CK = -5.973E-05 psi / Hz^2
Temperature factor: CT = -0.01615 psi / °F

Calculated pressure:

$$P\ (\text{psi}) = CF\ (L_1 - L_0) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

$$P\ (\text{psi}) = CK\ (F_1^2 - F_0^2) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu D J.
Date: 05/26/99

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CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99172**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**160 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3256.2	1790.6	-0.01
10.00	3074.0	1739.8	-0.05
20.00	2892.4	1687.6	-0.01
30.00	2710.4	1633.6	-0.04
40.00	2528.7	1577.9	-0.02
50.00	2347.0	1520.2	0.01
50.00	2347.0	1520.2	0.00
40.00	2528.9	1578.0	0.01
30.00	2710.9	1633.8	0.03
20.00	2892.9	1687.7	0.04
10.00	3074.5	1739.9	0.01
0.00	3256.5	1790.7	0.03
		Max error %:	0.05

Calibration factor: CF = **-5.499E-02 psi / LU**
CK = **-5.585E-05 psi / Hz^2**
Temperature factor: CT = **-0.00180 psi / °F**

Calculated pressure:

$$P\ (\text{psi}) = CF\,(L_1 - L_0) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

$$P\ (\text{psi}) = CK\,(F_1^2 - F_0^2) - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu
Date: 05/26/99

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CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99174
Range:	50 psi
Temperature:	75 °F
Barometric pressure:	29.53 inHg
Cable model:	IRC-41A
Cable length:	150 ft
Thermistor type:	2 kohms

Color code: red & black (coil) green & white (thermistor)

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3337.4	1812.8	-0.10
10.00	3168.3	1766.2	-0.03
20.00	2999.4	1718.5	0.07
30.00	2829.5	1669.1	0.06
40.00	2659.5	1618.2	0.02
50.00	2488.6	1565.4	-0.11
50.00	2488.6	1565.4	-0.11
40.00	2659.7	1618.3	0.05
30.00	2829.8	1669.2	0.09
20.00	2999.9	1718.7	0.13
10.00	3168.7	1766.3	0.02
0.00	3337.6	1812.8	-0.08
		Max error %:	0.13

Calibration factor: CF = -5.891E-02 psi / LU
CK = -5.983E-05 psi / Hz^2
Temperature factor: CT = -0.02079 psi / °F

Calculated pressure:

$$P\ (\text{psi}) = CF\ (L_1 - L_0) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

$$P\ (\text{psi}) = CK\ (F_1^2 - F_0^2) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no:	T100B951	Procedure:	PE100DRC
Filename:	052699A.xls		
Calibrated by:	Dorina Jugureanu	Date:	05/26/99

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CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	PWS
Serial number:	100D99170
Range:	50 psi
Temperature:	75 °F
Barometric pressure:	29.53 inHg
Cable model:	IRC-41A
Cable length:	190 ft
Thermistor type:	2 kohms

Color code: red & black (coil) . green & white (thermistor)

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3329.7	1810.7	-0.12
10.00	3152.4	1761.8	-0.01
20.00	2974.5	1711.4	0.03
30.00	2796.6	1659.4	0.07
40.00	2617.9	1605.5	0.01
50.00	2438.5	1549.5	-0.12
50.00	2438.8	1549.6	-0.09
40.00	2618.3	1605.6	0.06
30.00	2796.9	1659.5	0.09
20.00	2974.9	1711.5	0.07
10.00	3153.2	1762.0	0.08
0.00	3330.1	1810.8	-0.07
		Max error %:	0.12

Calibration factor: CF = -5.611E-02 psi / LU
CK = -5.698E-05 psi / Hz^2
ure factor: CT = -0.01632 psi / °F

Calculated pressure:

$$P\ (\text{psi}) = CF\ (L_1 - L_0) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

$$P\ (\text{psi}) = CK\ (F_1^2 - F_0^2) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951
Filename: 052699A.xls
Procedure: PE100DRC

Calibrated by: Dorina Jugureanu D.J.
Date: 05/26/99

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CALIBRATION DATA SHEET

VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D99169**
Range:	**50 psi**
Temperature:	**75 °F**
Barometric pressure:	**29.53 inHg**
Cable model:	**IRC-41A**
Cable length:	**400 ft**
Thermistor type:	**2 kohms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure psi	Reading linear unit LU	Reading frequency Hz	Full scale Error %
0.00	3281.2	1797.4	-0.16
10.00	3111.3	1750.3	-0.02
20.00	2941.1	1701.7	0.09
30.00	2770.0	1651.5	0.09
40.00	2598.4	1599.5	0.02
50.00	2426.0	1545.6	-0.12
50.00	2426.0	1545.5	-0.13
40.00	2598.5	1599.6	0.04
30.00	2770.2	1651.6	0.11
20.00	2941.4	1701.8	0.12
10.00	3111.7	1750.4	0.03
0.00	3282.1	1797.7	-0.06
		Max error %:	0.16

Calibration factor: CF = -5.844E-02 psi / LU
CK = -5.935E-05 psi / Hz^2
Temperature factor: CT = -0.01776 psi / °F

Calculated pressure:

$$P\ (\text{psi}) = CF\ (L_1 - L_0) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

$$P\ (\text{psi}) = CK\ (F_1^2 - F_0^2) - CT\ (T_1 - T_0) - 0.491\ (B_1 - B_0)$$

L_0, L_1 = Initial (at installation) and current reading, in LU
F_0, F_1 = Initial (at installation) and current reading, in Hz
T_0, T_1 = Initial (at installation) and current temperature, in °F
B_0, B_1 = Initial (at installation) and current barometric pressure, in inHg
0.491 = Constant for all vibrating wire sensors, in psi / inHg
LU = Linear unit with K = 1.0156, position 4, MB-6T readout

Traceability no: T100B951 Procedure: PE100DRC
Filename: 052699A.xls

Calibrated by: Dorina Jugureanu D.J. Date: 05/26/99

ROCTEST INC.

Geotechnical and
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VIBRATING WIRE PIEZOMETER

PW SERIES

INSTRUCTION MANUAL

This equipment should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the use thereof. The information herein is subject to change without notification.

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94 Industrial Blvd., Plattsburgh, New York USA 12901-2016 1(800) 477-2506 • Tel.: (518) 561-3300 • Fax: (518) 561-1192
E-mail : roctest@westelcom.com • Web site : http: //www.roctest.com

IRAD GAGE Reliable vibrating wire technology since 1970

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1 PRODUCT

The IRAD GAGE PW vibrating wire piezometer is a stable, robust pressure transducer, designed to allow remote measurements of piezometric level and pore pressure over long periods of time. The output is a frequency signal, unaffected by line impedance and contact resistance, allowing transmission over very long distances. It can be installed in boreholes (**model PWS**), driven into soft ground (**model PWP**), laid in trenches prior to fill replacement, or buried in concrete (**models PWS and PWF**). It can also be threaded to hydraulic or pneumatic lines (**model PWC**).

The standard integral thermistor measures the temperature of the gage and its surroundings.

Each gage is delivered with a Calibration Data Sheet, which includes a Calibration Factor and a Temperature Correction Factor. These factors are determined through factory calibration.

A portable readout unit, such as the MB-6T/6TL, displays the period of the vibrating wire, or a linearized value proportional to the pressure. Additionally, the readout unit will display the gage temperature directly in degrees Fahrenheit, or Celsius.

Complete data logging systems are available, please consult the Company for details.

1.1 GAGE CONSTRUCTION

The PW piezometer is a vibrating wire diaphragm pressure sensor. The sensing element is formed by welding a flexible diaphragm to a rigid cylindrical body. All parts of the sensor other than the wire are machined from a high-grade stainless steel, selected for its low yield and high corrosion resistance. A high strength steel wire is clamped to the center of the diaphragm, runs through the sensor, and is clamped to the back end block. The wire is clamped to the diaphragm and end block by hydraulic swaging, which virtually welds the parts together, without affecting the elastic properties of the wire. The wire is set to a pre-determined tension during manufacture, then evacuated and sealed with electron beam welding to ensure a long gage life. A coil/magnet assembly is used in conjunction with the MB-6T/6TL readout to excite the wire and measure the wire's vibration period.

Transducer is perfectly sealed thanks to watertight connector, potting, watertight feed through header, and o-rings (see Figure 1).

In use, pressure applied to the diaphragm causes it to deflect. This changes the wire tension and resonant frequency of the wire. The MB-6T/6TL readout accurately measures the period of the resonant frequency and displays either the period of wire vibration or a linear function of the period (frequency squared). The use of an equation with a gage factor for the piezometer enables the user to calculate pressure from the displayed readings.

1.1.1 Models PWS and PWC

The model PWS piezometer is designed to be embedded in earth fills and concrete, or inserted into boreholes and pipes as small as 19 mm (3/4"). It consists of a small diameter cylindrical housing containing a pressure transducer and thermistor (see Figure 1). One end is fitted with an insert that holds a micrometric high air or low air entry filter. The opposite end contains the cable entry, sealed with an epoxy compound. All parts are made of stainless steel.

The filter is set in the front end of the housing and sealed with an o-ring. With the filter in place, the diaphragm is protected from solid particles, and senses only the fluid pressure to be measured. The filter housing easily removable for calibration and saturation can also be replaced with a pipe thread adapter to use the gage as a pressure transducer. **(Model PWC).**

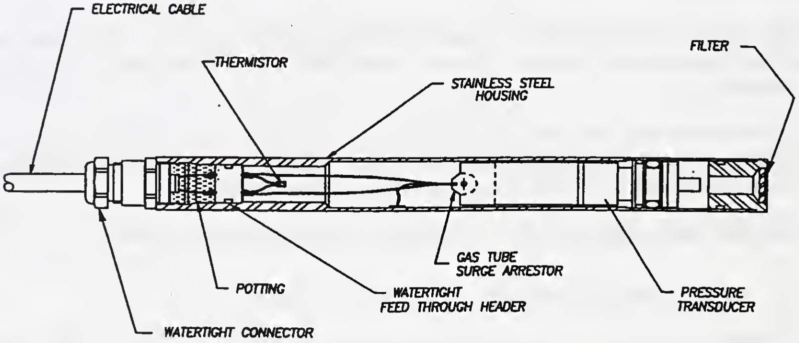


Figure 1: PWS Pressure Transducer

1.1.2 Model PWP

The model PWP piezometer is designed to be driven into unconsolidated fine grain materials such as sand, silt, or clay. The external housing is a thick walled cylinder fitted with a pointed shoe at one end, and a male thread adapter at the cable entry, fitting "EW" standard drill rods. Four port holes above the point hold micrometric filters. The cable passes through the threaded end, and can be fed through push rods leading to the surface. The cable entry is sealed with an epoxy compound. Both high and low air entry filters are available.

1.1.3 Model PWF

The model PWF piezometer is a thick wall version of the PWS piezometer.

1.2 VIBRATING WIRE PRINCIPLE

The sensing element of the piezometer is a piano wire attached to a diaphragm, excited by two coil/magnets set around the coil chamber. Pressure on the diaphragm changes the tension on the wire. The tension is directly proportional to the resonant, or natural frequency of the wire.

The MB-6T/6TL readout unit generates plucking voltages in the coil/magnet in a spectrum of frequencies, spanning the natural frequency of the wire, thus forcing the wire into vibration. In turn, the oscillation of the wire generates AC voltage in the coil. This signal is amplified by the readout unit, which also discriminates against harmonic frequencies, to determine the resonant frequency of the wire. The MB-6T/6TL times 100 cycles of vibration with a precise quartz oscillator, and displays either the period (inverse of frequency), or a value proportional to the frequency squared.

The relationship between the period (N) and the strain (ε) in the vibrating wire is expressed by the following equation:

$$\varepsilon = \frac{K \times 10^9}{N^2} \qquad (1)$$

Where: ε = µstrain

N = period of vibration in microseconds

K = 1.0156 for piezometers

The vibrating wire technology offers the unique advantage of a frequency output signal virtually unaffected by line impedance, or contact resistance. Cable lengths of up to one mile (1.6 km) can be used without signal deterioration.

1.3 CALIBRATION

All PW vibrating wire piezometers are individually calibrated before shipment. Each piezometer is calibrated over its working pressure range. The calibration factor is established by running the calibration data points through a linear regression formula. They are also tested at 150% of the working range, and for a temperature range from 2°C to 43°C (36 °F to 110 °F).

A Calibration Data Sheet supplied with each gage, lists the following:

- Serial Number
- Working pressure (in kPa or psi)
- Calibration Factor (NIST traceable)
- Temperature at time of factory calibration
- Barometric pressure at time of factory calibration
- Electrical cable type and length.

1.4 SPECIFICATIONS

PERFORMANCE	
Models:	PWS, PWP, PWC, PWF
Measuring range:	200, 350, 500, 750, 1000, 1500, 2000, 3000, 5000, 7000 kPa (1) 25, 50, 75, 100, 150, 250, 300, 500, 750, 1000 psi (1)
Resolution with MB-6T/6TL readout:	0.01% Full Scale
Accuracy:	0.5% Full Scale(2)
Maximum overload:	2 x measuring range
Diaphragm displacement:	0.001 cm^3 (6×10^{-5} in^3.) at full scale

(1) Other ranges available upon request.

(2) 0.25% and 0.1% FS linearity available upon request.

CONSTRUCTION				
Model:	PWS	PWP	PWC	PWF
Housing:	Miniature	Push-in point with EW thread	Threaded	Thick wall
Material:	Stainless steel			
Outside diameter in mm (in.):	19 (0.75)	33 (1.31)	19 (0.75)	28 (1.10)
Length in cm (in.):	20 (7.75)	26 (10.25)	21.3 (8.25)	22.5 (8.25)
Filters:	50 micron low air entry sintered stainless steel filters(standard) or 1.6 micron high air entry ceramic filters (optional)			

THERMISTOR AND ELECTRICAL CABLE	
Measuring range:	-40 to 65°C (-40 to +150°F)
Accuracy:	± 0.5°C (± 0.9°F)
Thermistor thermal constant:	1 min/°C (2 min/°F)
Electrical cable:	. IRC-41A: 2 twisted pairs, AWG 22, 6.2 mm OD, shielded, with drain wire (standard). . CP-455S: 2 twisted shielded pairs with central Kevlar armor, 20 AWG (optional with the PWF). . 1PBQFA: 2 twisted shielded pairs with steel jacket, 12 mm OD (optional with the PWF).
Wiring code:	See Calibration Data Sheet

CALIBRATION AND IDENTIFICATION

Labeled on housing:	- Serial number, and range in psi or kPa
Calibration chart:	- Calibration factor (NIST traceable) - Temperature correction factor - Barometric pressure at time of factory calibration - Temperature at time of factory calibration - Electrical cable type and length.

29.92

2 DATA READING AND ANALYSIS

2.1 PRE-INSTALLATION ACCEPTANCE READING

Gage readings should be taken as soon as the gages are received to ensure they have not been damaged during shipment. Zero readings should be compared with the factory readings after barometric and temperature corrections are made. Small variations may arise from shocks or excessive vibrations during transport and do not affect the linearity of the transducer or the calibration factor. Please review the instruction manual for the readout unit before proceeding with the reading.

2.2 PRE-INSTALLATION INITIAL READING

Before installing the piezometer, it is necessary to take an initial reading. The procedure for taking an initial reading is the following:

Take a pre-initial reading in air with the filter removed at a stabilized temperature and at a known barometric pressure. Record the linear reading, the temperature reading and the barometric pressure reading. Test gage in the same position in which it is to be installed.

Assemble the saturated porous element in a bucket filled with water onto the piezometer. The piezometer must be held tip up to ensure that no air bubbles are entrapped behind the filter. For lower pressure range transducers and for high air entry filters, monitor the pressure acting on the diaphragm to ensure it does not exceed 150 percent of the operating range of the piezometer. Use the readout unit and the calibration data sheet to evaluate the applied pressure. Leave the instrument in the water for 2 to 3 hours for the temperature to stabilize.

It is even preferable to leave it overnight provided that arrangements are made to keep the water at more or less uniform temperature. The instrument is temperature stabilized if the water temperature (ambient) is uniform. All sudden changes of temperature must be avoided.

With the water temperature, ambient temperature and piezometer temperature in equilibrium raise the piezometer by the electrical cable until it is out of the water and take a second reading. Record the stabilized value. Monitor 3 successive readings to ensure a stable value is recorded. This is the initial reading. Record ambient temperature and barometric pressure and the initial reading.

The pre-initial reading corrected for temperature and barometric pressure should be in agreement with the initial reading taken with the saturated filter on. The difference between the two readings for a properly installed and saturated filter should be within ±0.5%.

2.3 ON-SITE FUNCTION CHECK (OPTIONAL)

Piezometers are calibrated in factory with high precision calibrators having an accuracy at least four times better than the accuracy of the piezometer. However, it is tempting for the user to make function/calibration checks.

The preferred method for an on site function check is to carry out the readings in a water filled pipe at uniform temperature. Variables that otherwise may be present if the piezometer is checked in an open borehole (i.e. temperature gradients, flow, unknown density variations) and that were not present at time of factory calibration are eliminated.

The function check can be made relative to barometric pressure or to a difference of piezometric head in the pipe. In both cases, barometric pressure should be measured and recorded along with the readings. (A protected function check pipe may be installed in a borehole or in a building).

2.4 PRESSURE EQUATIONS (WITH THE MB-6T/6TL READOUT)

a) LINEAR readings (L)

The MB-6T/6TL LINEAR readings are converted to pressure using the equation below. The LINEAR readings must have been obtained with the GAUGE TYPE selector switch in the correct position on the MB-6T/6TL readout (position #4).

The PW series of vibrating wire piezometers measure absolute pressure and must be corrected for barometric pressure changes.

The piezometers are supplied with a temperature correction factor, which is used to correct the pressure reading for significant variations in temperature.

To convert changes in LINEAR readings to changes in pressure corrected for barometric pressure and temperature changes, use the following equation:

Imperial units (psi)

$$\Delta P = [C.F \times (L_0 - L_1)] - [T_K \times (T_0 - T_1)] + [0.491 \times (B_0 - B_1)] \qquad (2)$$

Where: ΔP = change in pressure in psi.

$C.F.$ = calibration factor in psi per LINEAR unit

L_0, L_1 = initial and current LINEAR readings

T_K = temperature correction factor from piezometer Calibration Data Sheet in psi/°F

T_0, T_1 = initial and current temperature readings (°F)

B_0, B_1 = initial and current barometric pressure reading in inches of Hg

0.491 = constant for all piezometers in psi/in. of Hg.

Example:

$C.F.$ = 0.050923 psi/LINEAR unit

L_0 = 3500 LINEAR units

L_1 = 2500 LINEAR units

T_K = -0.006696 psi/°F

T_0 = 50°F

T_1 = 40°F

B_0 = 31.2 in. Hg

B_1 = 29.4 in. Hg

ΔP = [(0.050923) x (3500 - 2500)] - [(-0.006696) x (50 - 40)] + [(0.491) x (31.2 - 29.4)]

ΔP = 50.923 + 0.067 + 0.884 = 51.874 psi

SI units (kPa)

$$\Delta P = [C.F \times (L_0 - L_1)] - [T_K \times (T_0 - T_1)] + [(B_0 - B_1)] \qquad (3)$$

where: ΔP = Change in pressure in kPa

C.F. = Calibration factor in kPa per LINEAR unit

L_0, L_1 = Initial and current LINEAR readings

T_K = Temperature correction factor from piezometer Calibration Data Sheet in kPa/°C

T_0, T_1 = Initial and current temperature readings (°C)

B_0, B_1 = Initial and current barometric pressure readings in kPa.

Example :

C.F. = 0.351114 kPa/LINEAR unit

L_0 = 3500 LINEAR units

L_1 = 2500 LINEAR units

T_K = -0.978781 kPa/°C

T_0 = 10°C

T_1 = 4.4°C

B_0 = 105.64 kPa

B_1 = 99.57 kPa

ΔP = [0.351114 x (3500 - 2500)] - [(-0.978781) x (10 - 4.4)] + [(105.64 - 99.57)]

ΔP = 351.114 + 5.481 + 6.07 = 362.67 kPa.

b) NORMAL readings (N)

The calibration factor on the piezometer calibration data sheet supplied with each PW series piezometer is expressed in psi per MB-6T/6TL LINEAR unit. To convert NORMAL readings to psi, the NORMAL readings must first be converted to LINEAR readings using the following equation:

$$L = \frac{K \times 10^9}{N^2} \qquad (4)$$

where: L = LINEAR reading in LINEAR units

K = gage constant for all piezometers = 1.0156

N = reading in the NORMAL mode in microseconds.

Example:

N = 575.0 µsec

$$\mathrm{L} = \frac{10156 \times 10^9}{(575.0)^2} = 30718 \text{ LINEAR units}$$

The LINEAR readings are then substituted in the equation (2) or (3).

2.5 PRESSURE EQUATIONS WITH A POLYNOMIAL REGRESSION (WITH THE MB-6T/6TL READOUT)

a) LINEAR readings (L)

The MB-6T/6TL LINEAR readings are converted to pressure using the equation below. The LINEAR readings must have been obtained with the GAUGE TYPE selector switch in the correct position on the MB-6T/6TL readout (position #4).

The PW series of vibrating wire piezometers measure absolute pressure and must be corrected for barometric pressure changes.

The piezometers are supplied with a temperature correction factor, which is used to correct the pressure reading for significant variations in temperature.

To convert changes in LINEAR readings to changes in pressure corrected for barometric pressure and temperature changes, use the following equation for a polynomial regression (see the Calibration Data Sheet):

Imperial units (psi)

$$\Delta P=\left[C_1\times(L_0-L_1)\right]+\left[C_2\times(L_0-L_1)^2\right]+\left[T_K\times(T_0-T_1)\right]+\left[0.491\times(B_0-B_1)\right] \qquad (5)$$

where: ΔP = change in pressure in psi

C_1, C_2 = polynomial factor

L_0, L_1 = initial and current LINEAR readings

T_K = temperature correction factor from piezometer Calibration Data Sheet in psi/°F

T_0, T_1 = initial and current temperature readings (°F)

B_0, B_1 = initial and current barometric pressure reading in inches of Hg

0.491 = constant for all piezometers in psi/in. of Hg.

Example:

C_1 = 0.052981 psi/**LINEAR** unit

C_2 = -2.835×10^{-7} psi/**LINEAR** unit^2

L_0 = 3500 **LINEAR** units

L_1 = 2500 **LINEAR** units

T_K = -0.006696 psi/°F

T_0 = 50°F

T_1 = 40°F

B_0 = 31.2 in. Hg

B_1 = 29.4 in. Hg

ΔP = $[(0.052981) \times (3500 - 2500)] + [(-2.835 \times 10^{-7}) \times (3500 - 2500)^2]$
$- [(-0.006696) \times (50 - 40)] + [(0.491) \times (31.2 - 29.4)]$

ΔP = $52.981 - 0.2835 + 0.067 + 0.884 = 53.649$ psi

SI units (kPa)

$$\Delta P = \left[C_1 \times (L_0 - L_1)\right] + \left[C_2 \times (L_0 - L_1)^2\right] - \left[T_K \times (T_0 - T_1)\right] + \left[(B_0 - B_1)\right] \qquad (6)$$

where: ΔP = change in pressure in kPa

C_1, C_2 = polynomial factors

L_0, L_1 = initial and current LINEAR readings

T_K = temperature correction factor from piezometer Calibration Data Sheet in kPa/°C

T_0, T_1 = initial and current temperature readings (°C)

B_0, B_1 = initial and current barometric pressure readings in kPa.

Example:

C_1 = 0.36112 kPa/LINEAR unit

C_2 = -3.787×10^{-8} kPa/LINEAR unit^2

L_0 = 3500 LINEAR units

L_1 = 2500 LINEAR units

T_K = -0.978781 kPa/°C

T_0 = 10 °C

T_1 = 4.4 °C

B_0 = 105.64 kPa

B_1 = 99.57 kPa

$$\Delta P = [0.36112 \text{ x } (3500 - 2500)] + [-3.787\text{x}10^{-6} \text{ x } (3500 - 2500)^2] - [(-0.978781) \text{ x } (10 - 4.4)] + [(105.64 - 99.57)]$$

$$\Delta P = 361.112 - 3.787 + 5.481 + 6.07 = 368.88 \text{ kPa}$$

b) NORMAL readings (N)

To convert NORMAL readings to psi, the NORMAL readings must first be converted to LINEAR readings using the following equation:

$$L = \frac{K \times 10^9}{N^2}$$

where: L = LINEAR reading in LINEAR units

K = gage constant for all piezometers = 1.0156

N = reading in the NORMAL mode in microseconds.

Example:

N = 575.0 µsec

$$\text{L} = \frac{1.0156 \times 10^9}{(575.0)^2} = 3071.8 \text{ LINEAR units}$$

The LINEAR readings are then substituted in the equations given in the previous section.

3 INSTALLATION

Vibrating wire piezometers can be installed in various ways to suit each individual application. Specific guidelines for the installation of piezometers have been set for piezometer installation by various agencies and specialists. A list of references is given in appendix.

The following instruction summarize the generally accepted practice for:

- filter saturation,
- cable identification,
- piezometers installed in clay fill, granular material or boreholes,
- piezometers driven into soft soil,
- cable routing.

3.1 FILTER SATURATION

Two types of filters are available; high air entry ceramic or low air entry sintered stainless steel filters. Saturation of the filter:

- reduces the possibility of filter clogging,
- decreases response time,
- ensures hydraulic continuity between the pore water and the piezometer diaphragm in unsaturated soils.

3.1.1 Low air entry sintered stainless steel filters

The filter on the PWS piezometer body is removed by holding the piezometer in one hand and pulling and twisting the filter housing with the other hand.

The filter on the PWP piezometer is removed by unscrewing the tapered point from the piezometer body.

Saturate the filter by placing it in a receptacle of clean boiling water.

Immerse the piezometer housing with the filter removed in a water bath. With the diaphragm end pointing upwards and submerged, reassemble the filter. Keep the piezometer submerged until ready to install.

3.1.2 High air entry ceramic filters

Follow the procedure described above. To saturate the filter, boil the porous ceramic filter for a minimum two-hour period.

Proceed as above to reassemble and store the piezometer.

3.2 INSTALLATION IN FILL

3.2.1 Compacted clay

Excavate a trench or recess about 30 cm (12") deep by about 0.8 m^2 (2.5 sq. ft). Form a cylindrical hole in the side wall of the trench. The hole diameter should be slightly smaller than the piezometer body.

Push the piezometer into the side of the hole. Make sure that the piezometer filter is in direct contact with the host material. If necessary to ensure continuity with the saturated high air entry filter and the pore water, smear the filter with a thin paste of the saturated material.

Before backfilling, the cable must be laid with the utmost care. Loop the cable around the recess, making sure it rests on a bed of hand placed and compacted screened clay.

Make sure that the cable does not cross over itself or other cables in the same area.

Backfill the recess with screened clay containing no particles larger than 2.5 mm (0.1") in diameter. The backfill should have a water content and density equal to that of the surrounding material.

Make sure that the cable is protected from potential damage caused by angular material, compacting equipment or stretching due to subsequent deformations during construction or fill placement.

3.2.2 Granular materials

Install the piezometer as described above in a recess excavated for this purpose. Place the piezometer within the trench, loop cable and backfill with screened material containing the same moisture content and compacted to the same density as the surrounding fill. In rock fill, it is necessary to place a graded filter around the piezometer. Use fine grain clean sand around the instrument and increase the particle size as the backfill proceeds outwards to the rock fill. The sand placed in the recess around the instrument and cable should range in size from 0.5 mm to 2.5 mm (.02 to .1") in diameter.

3.3 INSTALLATION IN BOREHOLES

The method used to install a piezometer in a borehole depends on the particular conditions in which the installation must be carried out. The method described below will cover most applications. Artesian conditions, borehole stability, available drilling equipment and sealing materials are among the factors, which will influence the method, chosen. For a description of other methods, please consult the references listed in Section 4.

The casing is driven 30 cm (12") below the required piezometer elevation. If the piezometer is to measure the pore water pressure in a specific horizon, it will be necessary to drive the casing 1 m (3') below the piezometer elevation to enable the placement of a bentonite pellet (Peltonite) seal at the hole bottom.

After driving the casing, wash until the water emerging from the hole runs clear.

If required, set the two foot bentonite seal at the bottom of the borehole. Raise the casing 15 cm (6"). Place the bentonite in six inch increments until the bentonite level is one foot below the piezometer elevation. Pull the casing as the bentonite is set in place. Be very careful not to plug or allow bentonite to stick to the inside walls of the casing. This is accomplished by making sure the bentonite level is at all times below the casing and by slowly dropping the bentonite pellets in single file down the hole. Trying to feed the bentonite pellets too rapidly will result in bridging of the pellets in the casing or borehole. This will make it extremely difficult to complete the seal. Tamping of compressed bentonite pellets is not required.

Prior to setting the sand in place, lower a cylindrical weight down the hole to ensure that the hole is clear from any obstructions and if necessary, rinse the borehole until clear water emerges.

In the same manner, place 30 cm (12") of fine, clean sand in 15 cm (6") increments below the level of the piezometer tip. Pull the casing as the backfilling with the sand proceeds. Lower the piezometer into the hole. Take the initial readings as described above.

Pull the casing 15 cm (6") and backfill with fine clean sand. Repeat until the sand and casing are 30 cm (12") above the top of the piezometer. Take another reading on the piezometer.

Lift the casing in 15 cm (6") increments and backfill with bentonite pellets until a minimum 1.3 m (4') seal has been formed. During the bentonite pellet placement keep the cable taut to prevent the pellets from hooking up in the casing. Pour the pellets in the hole one at a time to avoid bridging. If only one piezometer is to be installed in the hole, backfill the casing with a cement/bentonite grout. If more than one piezometer is to be installed in the hole, backfill with host material or sand/bentonite mixture to an elevation of four feet below the second piezometer, then use 1 m (3') of bentonite, 30 cm (12") of sand, then the piezometer. Proceed as described above.

Pull the casing. Do not rotate the casing during removal.

Once all casing is removed, top off the borehole with grout.

3.4 PIEZOMETERS DRIVEN IN SOFT GROUND

The model PWP is designed to be pushed into place from the surface in soft materials. For deeper installations where driving from the surface is impossible, the piezometer may be pushed into place from the bottom of a pre-drilled borehole.

The model PWP piezometer comes fitted with a male EW rod thread that screws directly onto EW rod.

The rods form an effective seal above the piezometer. Should other rods be adapted to push the piezometer in place it is important that the diameter of the first 1.2 to 1.5 m (4 to 5') of rod remains larger than the outside diameter of the PWP piezometer housing.

The first step is to lay a sufficient number of rods side by side, alternating a male thread beside a female thread.

The piezometer cable is threaded through the rods leaving a 30 to 60 cm (1 to 2') loop of cable laying flat on the ground each time the cable emerges from one rod and enters a subsequent rod.

Let about 7 m (23') of free cable extend beyond the lower extremity of the first rod. This (for 3 m or 10' rod lengths) should provide sufficient slack to allow easy manipulation of the rods as they are screwed together and pushed in place.

Screw the lower rod onto the piezometer. Use a pipe sealing compound on the threads to form a permanent seal, preventing porewater from flowing into the rod string, causing corresponding pressure drops.

Push the piezometer in place and monitor any pressure buildup at the tip. Should the pressure exceed the working pressure range, stop the driving and wait until the pressure dissipates.

In soils with high salt content it is necessary to use a nylon bushing between the PWP piezometer and the push rods to prevent apparent pore water pressure increases caused by hydrogen gas generation due to galvanic corrosion, or pressure increases caused by any electro-osmotic effect on the porewater.

3.5 CABLE IDENTIFICATION

The cables are identified with the serial number that is labeled on the piezometer housing. The serial number is stamped on a tag that is fastened to the readout end of the cable. Optional hot stamped markings along the entire length of the cable are available.

The latter facilitates instrument identification should the cables be accidentally cut or damaged during the installation. Should the cable be cut, we recommend the use of our high pressure cable splice kits, especially if the splice is located underwater.

3.6 CABLE ROUTING

3.6.1 Transition from vertical borehole to horizontal trench

The cable should be routed along a curved path as it goes from a vertical to the horizontal position. At the collar of the borehole, embed the cable along a large radius circular path within a cushion of screened sand and 5% bentonite mix, hand compacted to the surrounding fill density.

Piezometers installed to monitor rock contact zones are generally installed in shallow boreholes to protect them against concentrated loads or movements. Run cables emerging from these holes through the dam core and locate the vertical to horizontal cable transition zone above the rock surface. Do not lay the cable directly on rock.

3.6.2 Horizontal cable runs

Two methods are currently used to protect horizontal cable runs from damage. Embedment within selected materials on surface of the fill or in a trench within the fill. Only the latter is discussed here. Surface installations require continuous surveillance and protection from the earth moving equipment circulating on the fill. For a description of this method, please refer to Clements (1982), reference A-6 in Section 4.

Some of the more important considerations that must be given to horizontal cable runs are:

- Avoid traversing transition zones where large differential settlements could create excessive strain in the cable.
- Avoid cable splices - if necessary, use only our approved splice kits.
- Do not lay cables one on top of the other.
- Use horizontal snaking or vertical snaking of the cable within the trenches. For most materials, a pitch of 2 m (6') with an amplitude of 0.4 m (1.3') is suitable. In very wet clays increase the pitch to 1 m (3').
- Use a combination of horizontal and vertical snaking at transition zones.

The trench dimensions should be 25 cm (10") wider than the laid out width of the cable. The trench should be a minimum of 60 cm (2") deep. A 12 cm (5") bedding layer of minus 0.8 mm (0.4") sand is placed along the trench bottom. As required, bentonite must be added to the sand to form impervious sections or plugs.

The cable is then covered with one 15cm (6") lift of minus 0.8 mm (0.4") material.

Backfill the trench with selected material completely and compact the selected material with light hand operated machines.

During the cable routing, read the instruments at regular intervals to ensure continued proper functioning.

3.7 LIGHTNING PROTECTION

At all times during the installation of the piezometers, any cable that is exposed to potential damage by lightning must be protected.

A large grounded metal cage placed over the cable bundle, combined with direct grounding of all leads and shields is an effective way to prevent lightning damage to the instruments and cables during the installation process.

A surge and overvoltage protection is included inside the body of the piezometer. It protects the vibrating wire only and not the thermistor. It consists of a double gas tube surge arrestor.

Additional sources of information on protecting instruments, junction boxes and data logging systems against power surges, transients and electromagnetic pulses are listed in references A-7, A-8 and A-9 in Section 4. (All junction boxes and data logging systems furnished by the Company are available with lightning protection).

4 MISCELLANEOUS

REFERENCES:

A-1 Terzaghi, K., and R. B. Peck. *Soil Mechanics in Engineering Practice*, John Wiley and Sons, Inc., 1967. (Article 68 of Chapter 12 provides a survey of tip types and recommendations on installation procedure.)

A-2 U. S. Department of the Interior, Bureau of Reclamation. *Earth Manual*, U. S. Government Printing Office, Washington 1974. (Designations E-27 and E-28 in the appendix give detailed guidance on piezometer installation in dam foundations.)

A-3 Bishop, A. W., P. R. Vaughan, and G. E. Green (1969), Report on specialty session, *Pore Measurements in the Field and in the Laboratory*, Proc. 7th, Int. Conf. Soil Mech. and Found. Eng. 3, 427. (A review of recent practice and instrumentation, related principally to earth structures.)

A-4 *Suggested Methods for Determining In-Situ Permeability, Groundwater Pressure and Flow*, Int. Soc. for Rock Mechanics, Committee on Field Tests (Draft report, 1974 - Final report in course of preparation.)

A-5 Hanna, T.H. *Foundation Instrumentation*, Trans. Tech. Publications, Ohio, USA, 1973. (Chapter 3 describes different types of piezometer tips, methods of installation, methods of recording and the protection of piezometers.)

A-6 Clements, D. J., and A. C. Durney (1982), *Instrumentation Developments*, proceedings of the Autumn Conference on the British National Committee on Large Dams (BNCOLD) Keele University, Institution of Civil Engineers, London, pp. A5-55.

A-7 General Electric (1976), *Transient voltage suppression manual*, G.E. Semiconductor Products Department, Syracuse, New York.

A-8 Baker, C. (1978), *Surge Protection for Instrumentation*, proceedings of the Tempcon Conference, London. Available from Measurement Technology, Inc., 7541 Gary Road, Manassas, Virginia, 22110, USA.

A-9 Baker, C. (1980), *Protecting Electronic Circuits from Lightening and Transients*. Available from Measurement Technology, Inc., 7541 Gary Road, Manassas, Virginia, 22110, USA.

A-10 Corps of Engineers (1984), *Publications Relating to Geotechnical Activities*, USACE DAENECE-G, September 27th.

APPENDIX H

DATA LOGGER OPERATION

DOWNLOAD DATALOGGER

(Wait until after 0900 to do this to be sure new data is posted.)

1. If laptop is not on, turn it on. The "ON" switch is 2 inches to the left of the State PAMS ID #3447.
2. Double click "TRD Piezo" icon toward right side of monitor.
3. Sing click "Connect" icon-second icon from left at top of screen.
   NOTE: A couple of times this software automatically connected to the datalogger, if that appears to have happened, skip to Step #6.
4. Under "Station List" highlight "CR10X1" if it is not already highlighted.
   NOTE: "CR10X1" downloads the data logged since the last connection and overwrites it to a file named "House.dat" to be used later.
5. Click "Connect" (lower right portion of screen).
6. After computer is connected to datalogger, click "Collect" (up and left from middle portion of screen).
7. In status bar titled "% Collected", "100%" will flash when done.
8. Click "Disconnect" in lower right portion of screen.
9. **IGNORE CR10X2 AND CR10X3.**
10. Close this window (Single click on "X" in upper right corner of screen.
11. Close software with single click on "X" in upper right corner of toolbar.

UPDATE STANDPIPE SPREADSHEET:

1. Double click "Microsoft Excel" icon.
2. Single click on "File" in upper left corner of toolbar.
3. Go to lower area of the "File" window and click on "Standpipes.xls".
4. If you are not already on the 'RAW DATA' tab on the lower left toolbar, click on the 'RAW DATA' tab. You may have to use the scroll buttons in the far lower left corner to get there.
5. Position the cursor in the first empty cell in Column A (the "DATE" column) and enter the date. If you key in 5/22 (or whatever), Excel will add the /00.
6. Scroll right and enter the reservoir elevation.
7. Scroll right two cells and begin entering piezometer reading in appropriate columns. Watch for anomalies.
8. After entering the reading for Piezo #214, enter flume and weir readings in appropriate columns.
9. Scroll back to Column A and **SAVE the spreadsheet.**
10. Click on the "Graph 1" tab, and check to see if it appears that the data is plotted OK. If it's Friday, print the graph and fax it to Kevin with all piezometer plots.
11. Repeat Step #10 for "Graphs 2 through 7" and "Flumes and Weirs".
12. Close the "Standpipes.xls" spreadsheet.

UPDATE VIBRATING WIRE SPREADSHEET:

1. Double click "Microsoft Excel" icon.
2. Single click on "File" in upper left corner of toolbar.
3. Go to lower area of the "File" window and click on "House.dat".
4. "Text Import Wizard-Step 1 of 3" will appear. Click on "Next>" in lower right part of window.
5. "Text Import Wizard –Step 2 of 3" appears. Click in the box to the left of "Comma". A check mark will appear in the box.
6. Click "Next>"
7. "Text Import Wizard-Step 3 of 3" appears. Click "Finish".
8. You should have one row of data in the spreadsheet.
9. Highlight that entire row of data.
10. Right click
11. Lift click "Copy"
12. Close the "House.dat" spreadsheet, but **NOT** Excel.
13. Click "File"
14. Go down and click on "VW2001.xls".
15. A window comes up that says, "The workbook you opened contains automatic links to information in another workbook. Etc, etc, etc".
16. Click "Yes"
    NOTE: You've just imported today's reservoir elevation so you don't have to manually go to another tab just to enter the elevation.
17. If you are not already on the "RAWDATA1" tab on the scroll bar in the lower left, click on "RAWDATA1". You may have to use the scroll buttons in the far lower left corner to get there.
18. Position cursor in the first empty cell in Column A (below last row of existing data).
19. Right click
20. Left click "Paste". The row of data you copied from "House.dat" should appear.
21. **SAVE** the spreadsheet.

22. Click on "PiezPlot" tab. Check to see if it appears data is plotted OK.
23. Repeat step #22 for "PiezPlot2"
24. Close Excel

APPENDIX I

SURVEY MONUMENTS

TABLE 10. TONGUE RIVER DAM SURVEY MONUMENTS

POINT	COMMENTS	COORDINATES			XREF
		N	E	Z	
1	BM #1	425053.52	2704246.00	3494.13	WWC 201
2	CP 504	424933.43	2704294.74	3476.00	
3	CP 520	425300.00	2704586.91	3463.78	
4	outlet centerline	425323.82	2704716.42	3386.07	
5	left upstream wall end	424949.92	2704557.36	3445.09	
6	left upstream wall	425045.46	2704616.09	3437.46	
7	left bridge centerline	425145.50	2704668.12	3439.16	
8	left downstream wall	425215.30	2704704.98	3430.20	
9	primary floor upstream centerline	TO BE SURVEYED 2002			
10	primary floor downstream centerline	425219.49	2704763.69	3409.26	
11	right upstream wall end	424786.48	2704728.09	3445.40	
12	right upstream wall	424977.52	2704705.66	3445.43	
13	right bridge centerline	425099.91	2704771.62	3436.59	
14	right downstream wall	425199.49	2704809.08	3429.12	
15	right downstream wall end	425336.25	2704869.30	3392.12	
16	auxillary spillway floor centerline	424368.23	2705411.64	3428.62	
17	auxilliary spillway crest - leftside	424490.16	2705262.54	3431.51	
18	auxilliary spillway crest - middle	424378.42	2705417.39	3431.48	
19	auxilliary spillway crest - rightside	424266.16	2705573.08	3431.43	
20	BM #2	423745.23	2706231.53	3457.52	WWC 202
21	Slide 1	423181.39	2705393.61	3465.11	WWC 81
22	Slide 2	423062.58	2705393.14	3493.37	WWC 82
23	Slide 3	422993.29	2705328.02	3495.66	WWC 83
24	Slide 4	422915.32	2705249.05	3500.25	WWC 84
25	Slide 5	422867.85	2705190.45	3492.58	WWC 85
26	SEC CRN 13-24-18-19	422440.57	2705171.20	3634.00	WWC 502
27	BM #3	422906.49	2705547.49	3601.59	WWC 203

Note: Points 26 and 27 are located on the ridge above the slide area.

APPENDIX J

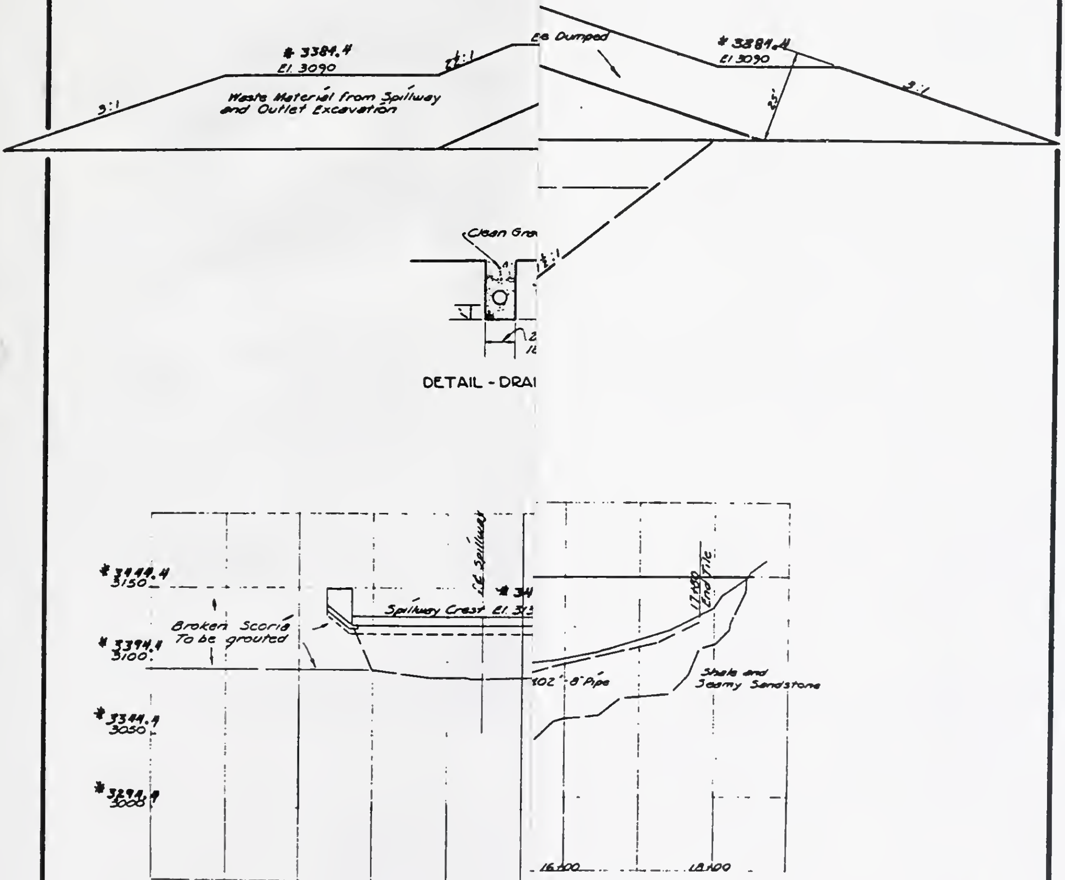
PROJECT DRAWINGS

(NOTE: The reduced project drawings are a combination of design drawings and "As Builts". The design drawing are stamped "Approved For Construction" and should be used for reference only. The "As Builts" are stamped "Record Drawings". The SWPB has the full size project drawings.)

INDEX OF DRAWINGS

Sheet		Page
3	Dam Cross Section	J3
C-1	Primary Spillway and Outlet Works Site Plan	J5
C-16	Primary Outlet Works Plan And Profile	J7
S-55	Intake Structure Plan And Sections	J9
S-58	Inlet Structure Reinforcing And Grating Details	J11
S-50	Primary Outlet Works Tunnel Cross Sections	J13
C-17	Primary Outlet Works Gate Structure Plan And Sections	J15
S-69	Outlet Works Downstream Area Plan	J17
C-18	Auxiliary Outlet Works Plan And Profile	J19
1054D	Inlet Structure	J21
S-90	Auxiliary Outlet Works Intake Structure Inlet Bulkhead	J23
C-19	Auxiliary Outlet Works Gate Structure Plan	J25
C-20	Auxiliary Outlet Works Gate Structure Section	J27
C-21	Emergency (Fixed Wheel) Gate Assembly	J29
	Gate Hydraulic Schematic	J31
	Gate Electrical Schematic	J33
C-45	West Abutment Piping Control Measures Plan And Profile	J35
C-48	West Abutment Piping Control Measures Sections	J37
C-5	Primary spillway Profile	J39
C-14.1	Primary Spillway Drainage System Plan	J41
S-92	Emergency Spillway Ogee Crest Plan And Sections	J43
S-2	Structural Centerline Section	J45
S-5	Structural Jointing Plan	J47
S-6	Structural End Sill	J49
S-8	Structural Steps	J51
S-19	Structural Precast Panels - Details	J53
E-16	Earthwork Toe Drain - Section	J55
D-1	Drainage System Plan And Profile	J57
D-5	Drainage Flume Vault Plan	J59
S-21	Structural Flume Vault	J6

Prior To 1996 - 2001
Rehabilitation

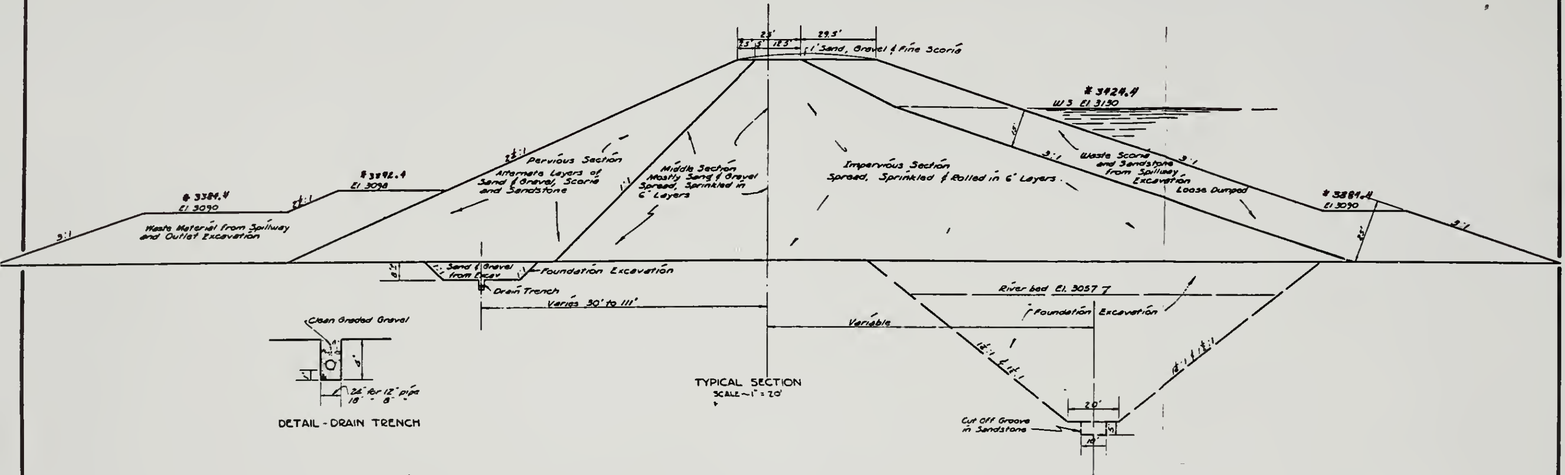


TYPICAL SECTION & PROFILE OF DAM AS CONSTRUCTED
TONGUE RIVER STORAGE PROJECT
BIG HORN & ROSEBUD COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA FEB. 1942
SCALE AS SHOWN

DWG. No. 1-8

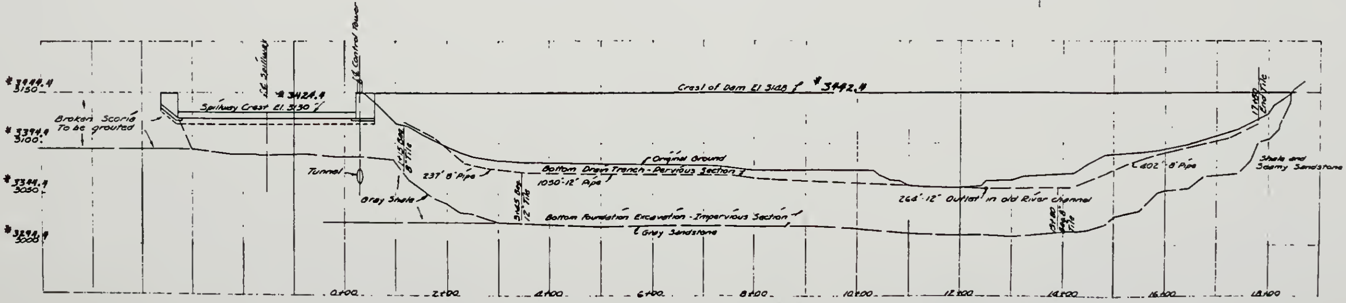
PLATE 3

Prior To 1996 - 2001
Rehabilitation



DETAIL - DRAIN TRENCH

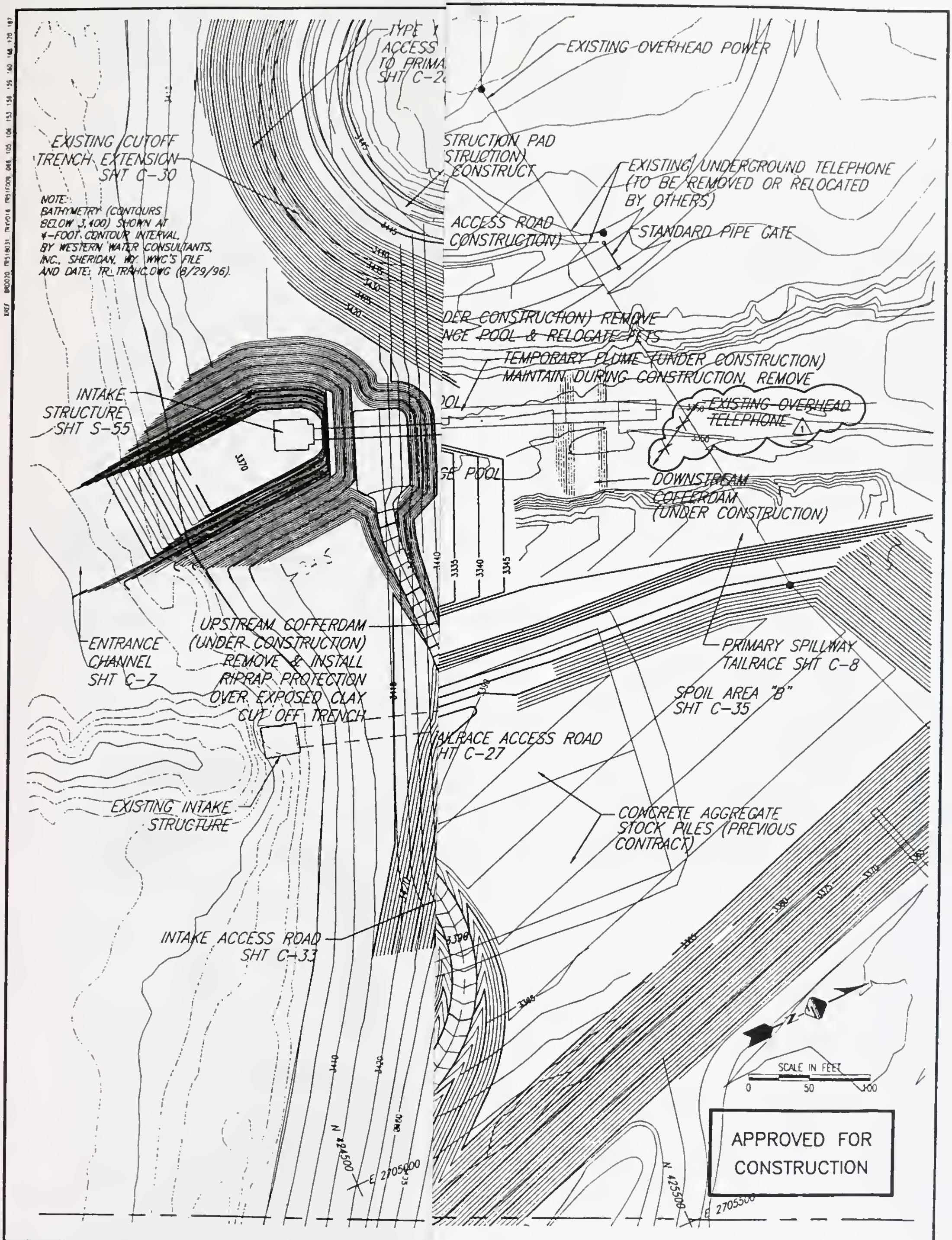
TYPICAL SECTION
SCALE ~ 1" = 20'



PROFILE
SCALE ~ HOR 1" = 100'
VERT 1" = 50'

* Based on U.S.B.R. Datum

TYPICAL SECTION & PROFILE OF DAM AS CONSTRUCTED
TONGUE RIVER STORAGE PROJECT
BIG HORN & ROSEBUD COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA FEB. 1942
SCALE AS SHOWN
DWG Nº 1-B



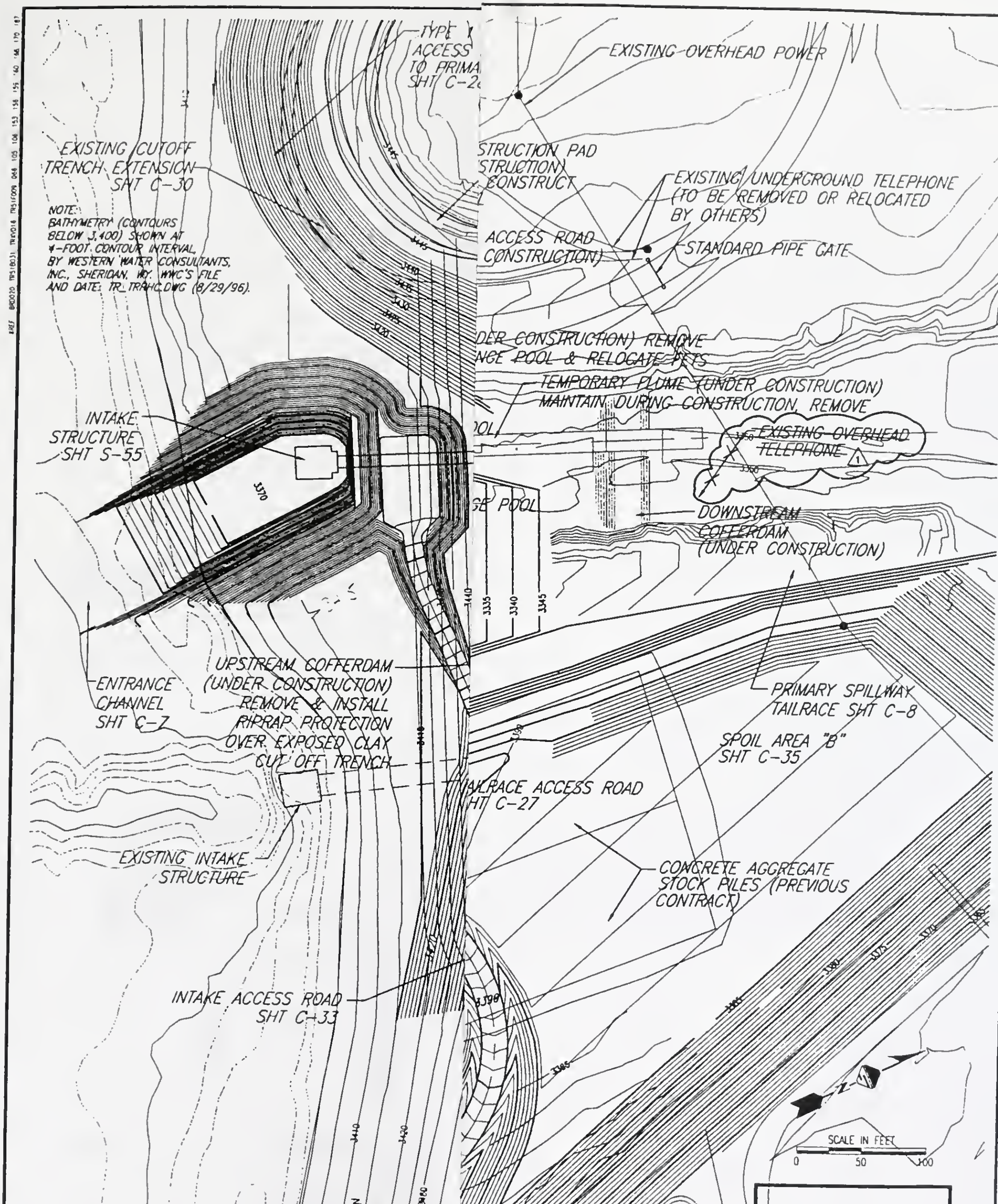
APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
2			SPOIL AREA TOPO MODIFIED AS RESULT OF ADDENDUM #3, ITEM 18
1			DELETED NOTE AND ARROW, ADDENDUM #3, ITEM 15

RIMARY SPILLWAY AND OUTLET WORKS
SITE PLAN

J5

SHEET
C-1


TYPE
ACCESS
TO PRIMA
SHT C-2
EXISTING OVERHEAD POWER
EXISTING CUTOFF TRENCH EXTENSION SHT C-30
STRUCTION PAD
STRUCTION)
CONSTRUCT
EXISTING UNDERGROUND TELEPHONE (TO BE REMOVED OR RELOCATED BY OTHERS)
ACCESS ROAD
CONSTRUCTION)
STANDARD PIPE GATE
DER CONSTRUCTION) REMOVE
NGE POOL & RELOCATE PETS
TEMPORARY FLUME (UNDER CONSTRUCTION) MAINTAIN DURING CONSTRUCTION, REMOVE
OOL
EXISTING OVERHEAD TELEPHONE
INTAKE STRUCTURE SHT S-55
GE POOL
DOWNSTREAM COFFERDAM (UNDER CONSTRUCTION)
UPSTREAM COFFERDAM (UNDER CONSTRUCTION) REMOVE & INSTALL RIPRAP PROTECTION OVER EXPOSED CLAY CUT OFF TRENCH
ENTRANCE CHANNEL SHT C-7
PRIMARY SPILLWAY TAILRACE SHT C-8
SPOIL AREA "B" SHT C-35
TAILRACE ACCESS ROAD SHT C-27
EXISTING INTAKE STRUCTURE
CONCRETE AGGREGATE STOCK PILES (PREVIOUS CONTRACT)
INTAKE ACCESS ROAD SHT C-33
3370
3345
3340
3335
3410
3390
3385
3380
3375
3370
3350
3430
N 424500
E 2705000
N 425500
E 2705500
N
SCALE IN FEET
0
50
100

NOTE:
BATHYMETRY (CONTOURS BELOW 3,400) SHOWN AT 4-FOOT CONTOUR INTERVAL BY WESTERN WATER CONSULTANTS, INC., SHERIDAN, WY. WWC'S FILE AND DATE: TR_TRHC.DWG (8/29/96).

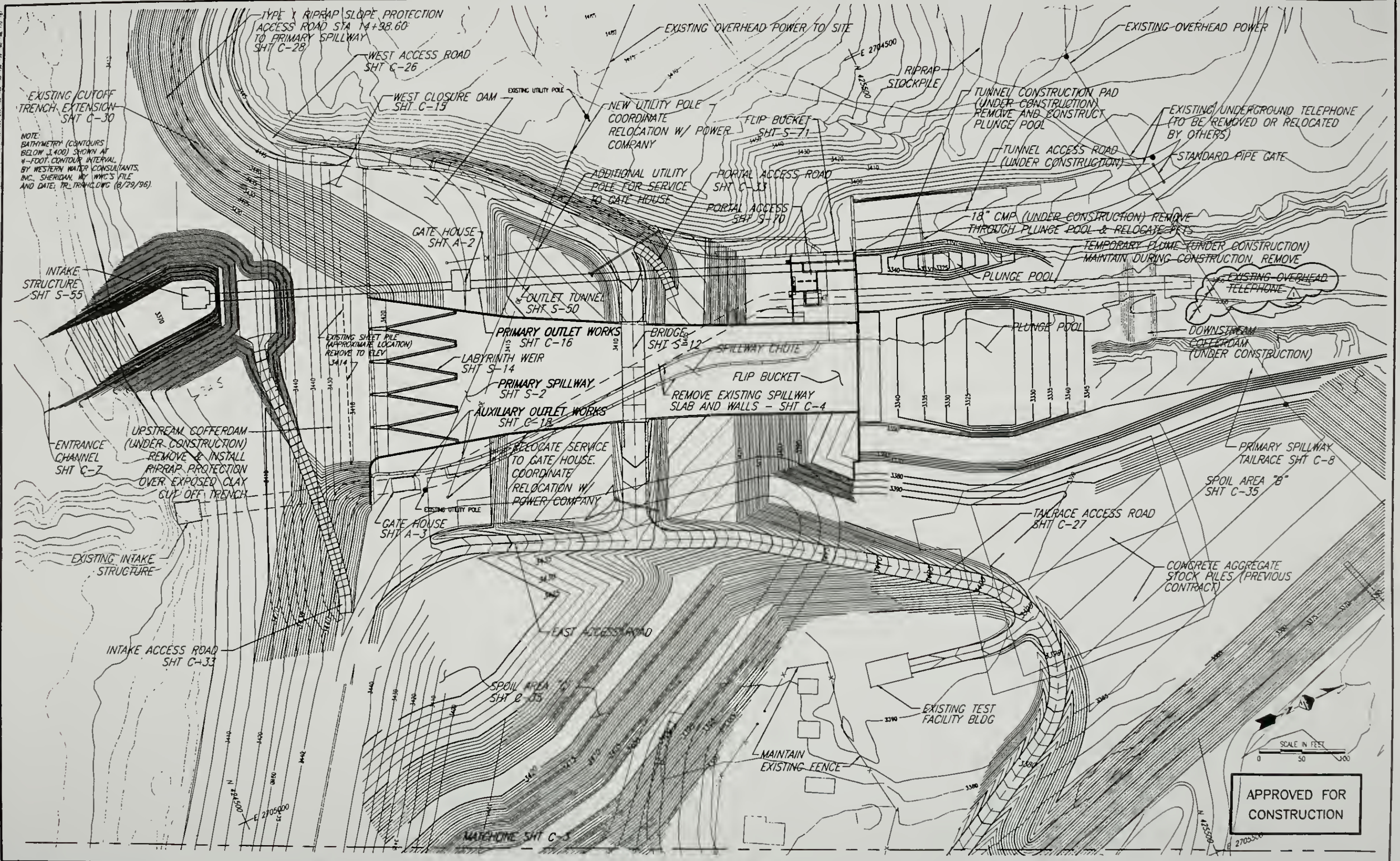
APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
2			SPOIL AREA TOPO MODIFIED AS RESULT OF ADDENDUM #3, ITEM 18
1			DELETED NOTE AND ARROW, ADDENDUM #3, ITEM 15

RIMARY SPILLWAY AND OUTLET WORKS
SITE PLAN

J5

SHEET
C-1


TYPE 1 RIPRAP SLOPE PROTECTION ACCESS ROAD STA 14+98.60 TO PRIMARY SPILLWAY SHT C-28
WEST ACCESS ROAD SHT C-26
EXISTING OVERHEAD POWER TO SITE
E 2704500
N 425500
RIPRAP STOCKPILE
EXISTING OVERHEAD POWER
EXISTING CUTOFF TRENCH EXTENSION SHT C-30
WEST CLOSURE DAM SHT C-15
EXISTING UTILITY POLE
NEW UTILITY POLE COORDINATE RELOCATION W/ POWER COMPANY
FLIP BUCKET SHT S-71
TUNNEL CONSTRUCTION PAD (UNDER CONSTRUCTION) REMOVE AND CONSTRUCT PLUNGE POOL
EXISTING UNDERGROUND TELEPHONE (TO BE REMOVED OR RELOCATED BY OTHERS)
TUNNEL ACCESS ROAD (UNDER CONSTRUCTION)
STANDARD PIPE GATE
ADDITIONAL UTILITY POLE FOR SERVICE TO GATE HOUSE
PORTAL ACCESS ROAD SHT C-33
PORTAL ACCESS SHT S-70
18" CMP (UNDER CONSTRUCTION) REMOVE THROUGH PLUNGE POOL & RELOCATE PETS
TEMPORARY FLUME (UNDER CONSTRUCTION) MAINTAIN DURING CONSTRUCTION, REMOVE
GATE HOUSE SHT A-2
PLUNGE POOL
EXISTING OVERHEAD TELEPHONE
INTAKE STRUCTURE SHT S-55
OUTLET TUNNEL SHT S-50
PRIMARY OUTLET WORKS SHT C-16
BRIDGE SHT S-12
SPILLWAY CHUTE
PLUNGE POOL
DOWNSTREAM COFFERDAM (UNDER CONSTRUCTION)
EXISTING SHEET PILE (APPROXIMATE LOCATION) REMOVE TO ELEV 3414
LABYRINTH WEIR SHT S-14
FLIP BUCKET
PRIMARY SPILLWAY SHT S-2
REMOVE EXISTING SPILLWAY SLAB AND WALLS - SHT C-4
AUXILIARY OUTLET WORKS SHT C-18
UPSTREAM COFFERDAM (UNDER CONSTRUCTION) REMOVE & INSTALL RIPRAP PROTECTION OVER EXPOSED CLAY CUT OFF TRENCH
ENTRANCE CHANNEL SHT C-7
RELOCATE SERVICE TO GATE HOUSE. COORDINATE RELOCATION W/ POWER COMPANY
PRIMARY SPILLWAY TAILRACE SHT C-8
SPOIL AREA "B" SHT C-35
EXISTING UTILITY POLE
GATE HOUSE SHT A-3
TAILRACE ACCESS ROAD SHT C-27
EXISTING INTAKE STRUCTURE
CONCRETE AGGREGATE STOCK PILES (PREVIOUS CONTRACT)
EAST ACCESS ROAD
INTAKE ACCESS ROAD SHT C-33
SPOIL AREA "C" SHT C-35
EXISTING TEST FACILITY BLDG
MAINTAIN EXISTING FENCE
SCALE IN FEET
0
50
100
N 424500
E 2705000
MATCHLINE SHT C-3
N 425500
E 2705500
3340
3335
3330
3325
3345
3380
3390
3400
3410
3420
3430
3440

NOTE:
BATHYMETRY (CONTOURS BELOW 3,400) SHOWN AT 4-FOOT CONTOUR INTERVAL BY WESTERN WATER CONSULTANTS, INC., SHERIDAN, WY WWC'S FILE AND DATE: TR_TRAHC.DWG (8/29/96).

APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
2			SPOIL AREA TOPO MODIFIED AS RESULT OF ADDENDUM #3, ITEM 18
1			DELETED NOTE AND ARROW ADDENDUM #3, ITEM 15

BMG/MAK DRAWN	STN DESIGNED	STN CHECKED
WRK APPROVED	7/97 DATE	141.9501 PROJECT NO.

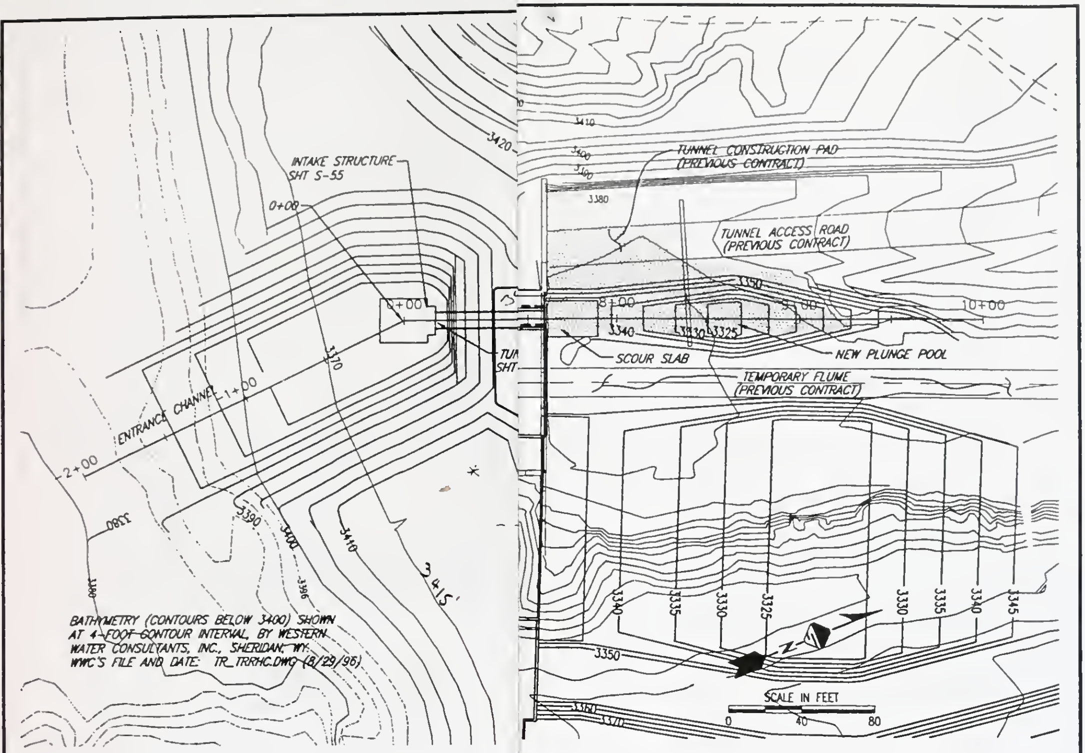
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

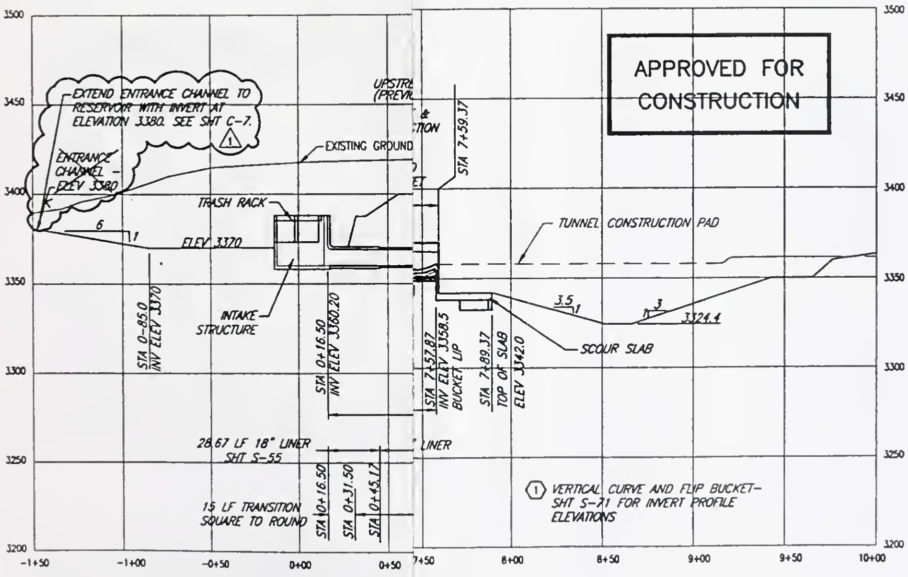
PRIMARY SPILLWAY AND OUTLET WORKS
SITE PLAN

J5

SHEET
C-1



BATHYMETRY (CONTOURS BELOW 3400) SHOWN AT 4-FOOT CONTOUR INTERVAL, BY WESTERN WATER CONSULTANTS, INC., SHERIDAN, WY. WWC'S FILE AND DATE: TR_TRRHC.DWG (8/29/96)



APPROVED FOR CONSTRUCTION

① VERTICAL CURVE AND FLIP BUCKET-SHT S-71 FOR INVERT PROFILE ELEVATIONS

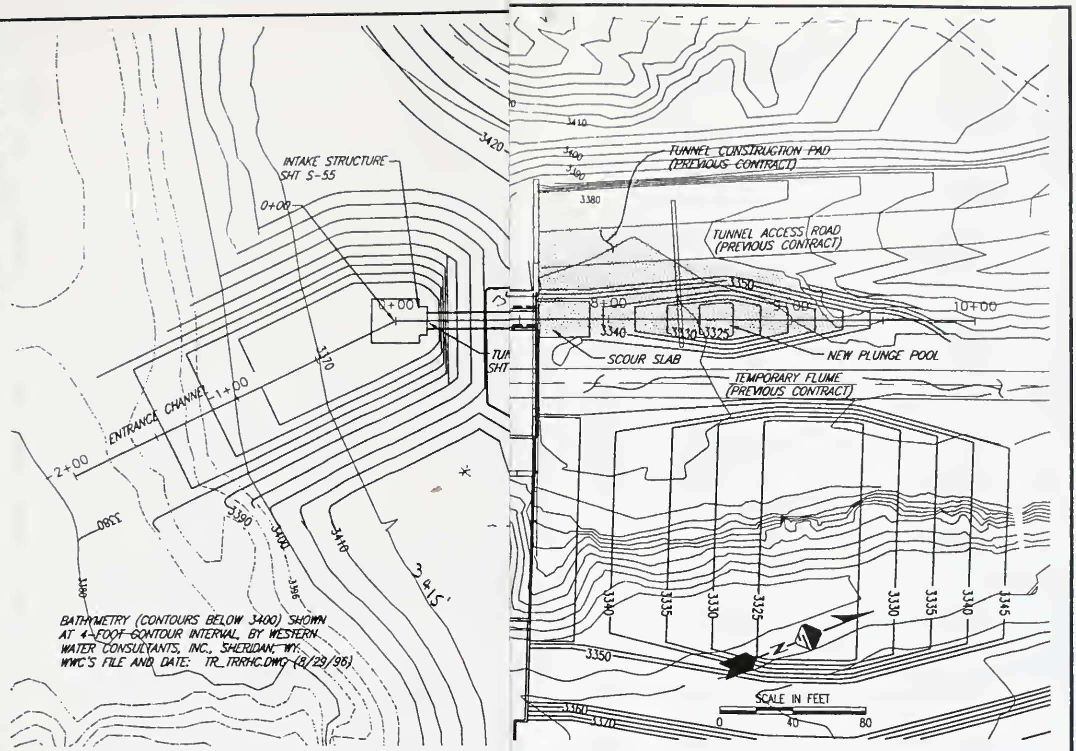
NO	BY	DATE	REVISION DESCRIPTION
1			CHANGE NOTE, ADDENDUM 3, ITEM 17

PRIMARY OUTLET WORKS
PLAN AND PROFILE

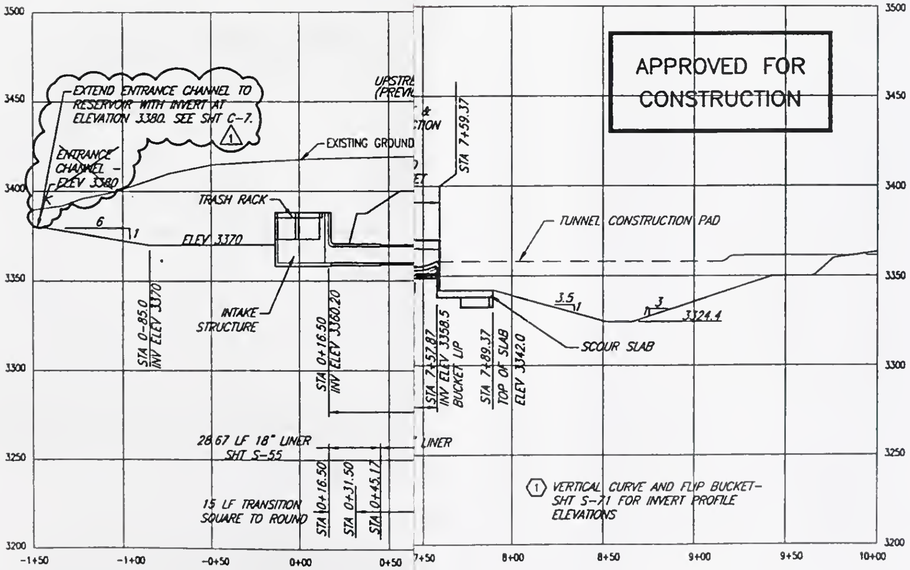
J7

SHEET
C-16

DWG TR51F875



BATHYMETRY (CONTOURS BELOW 3400) SHOWN AT 4-FOOT CONTOUR INTERVAL, BY WESTERN WATER CONSULTANTS, INC., SHERIDAN, WY. WWC'S FILE AND DATE: TR_TRRHC.DWG (8/29/96)



① VERTICAL CURVE AND FLIP BUCKET-SHT S-71 FOR INVERT PROFILE ELEVATIONS

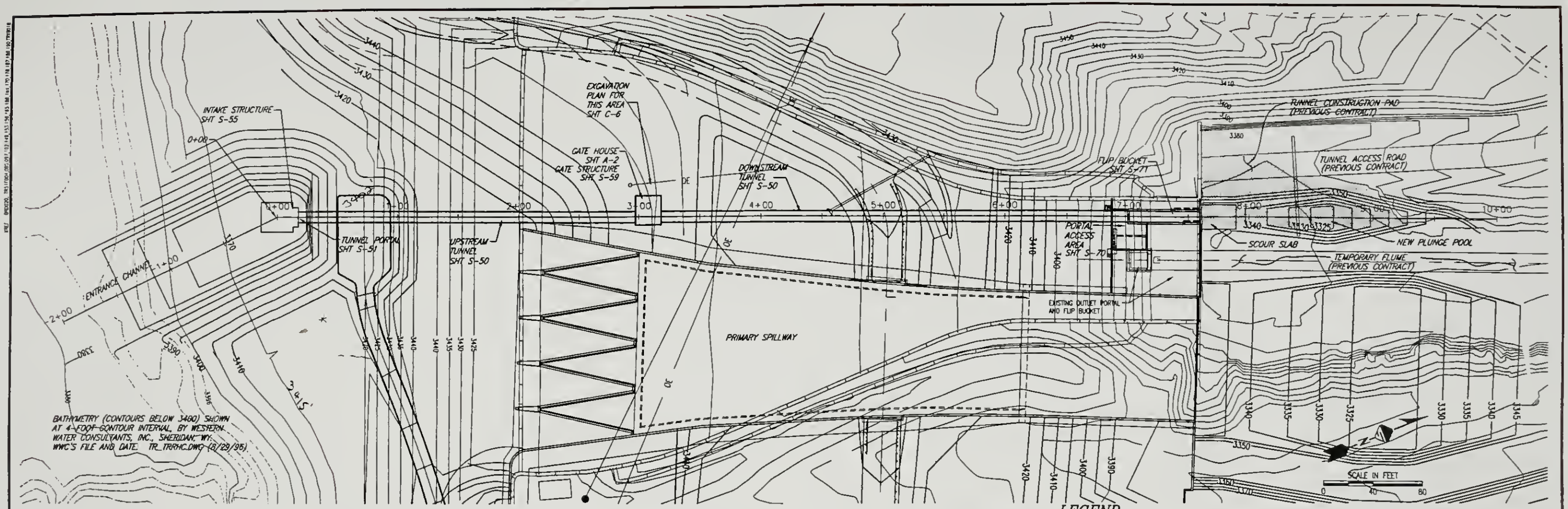
APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
1			CHANGE NOTE, ADDENDUM 3, ITEM 17

PRIMARY OUTLET WORKS
PLAN AND PROFILE

J7

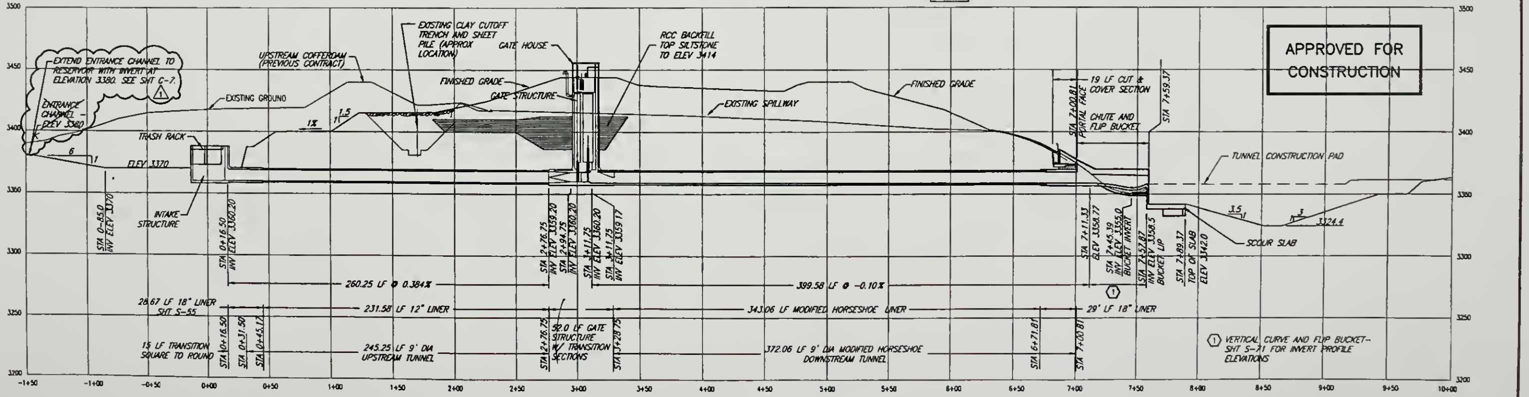
SHEET
C-16


INTAKE STRUCTURE SHT S-55
0+00
EXCAVATION PLAN FOR THIS AREA SHT C-6
GATE HOUSE SHT A-2
GATE STRUCTURE SHT S-59
DOWNSTREAM TUNNEL SHT S-50
FLIP BUCKET SHT S-71
TUNNEL CONSTRUCTION PAD (PREVIOUS CONTRACT)
TUNNEL ACCESS ROAD (PREVIOUS CONTRACT)
TUNNEL PORTAL SHT S-51
UPSTREAM TUNNEL SHT S-50
ENTRANCE CHANNEL
PORTAL ACCESS AREA SHT S-70
SCOUR SLAB
NEW PLUNGE POOL
TEMPORARY FLUME (PREVIOUS CONTRACT)
EXISTING OUTLET PORTAL AND FLIP BUCKET
PRIMARY SPILLWAY
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
-1+00
-2+00
3440
3430
3420
3410
3400
3390
3380
3370
3350
3340
3335
3330
3325
3345
BATHYMETRY (CONTOURS BELOW 3400) SHOWN AT 4-FOOT CONTOUR INTERVAL, BY WESTERN WATER CONSULTANTS, INC., SHERIDAN, WY. WWC'S FILE AND DATE: TR_TRRHC.DWG (8/29/95).
SCALE IN FEET
0
40
80
N

PLAN

LEGEND

▨ TUNNEL CONSTRUCTION PAD SURFACE


EXTEND ENTRANCE CHANNEL TO RESERVOIR WITH INVERT AT ELEVATION 3380. SEE SHT C-7. 1
~~ENTRANCE CHANNEL - ELEV 3380~~
EXISTING GROUND
UPSTREAM COFFERDAM (PREVIOUS CONTRACT)
EXISTING CLAY CUTOFF TRENCH AND SHEET PILE (APPROX LOCATION)
GATE HOUSE
FINISHED GRADE
GATE STRUCTURE
RCC BACKFILL TOP SILTSTONE TO ELEV 3414
EXISTING SPILLWAY
FINISHED GRADE
TRASH RACK
ELEV 3370
1%
1.5
1
6
1
INTAKE STRUCTURE
STA 0-85.0 INV ELEV 3370
STA 0+16.50 INV ELEV 3360.20
STA 2+76.75 INV ELEV 3359.20
STA 2+94.75 INV ELEV 3360.20
STA 3+11.75 INV ELEV 3360.20
STA 3+11.75 INV ELEV 3359.17
260.25 LF @ 0.384%
399.58 LF @ -0.10%
28.67 LF 18" LINER SHT S-55
231.58 LF 12" LINER
343.06 LF MODIFIED HORSESHOE LINER
29' LF 18" LINER
15 LF TRANSITION SQUARE TO ROUND
STA 0+16.50
STA 0+31.50
STA 0+45.12
245.25 LF 9' DIA UPSTREAM TUNNEL
STA 2+76.75
52.0 LF GATE STRUCTURE W/ TRANSITION SECTIONS
STA 3+28.75
372.06 LF 9' DIA MODIFIED HORSESHOE DOWNSTREAM TUNNEL
STA 6+71.81
STA 7+00.81
19 LF CUT & COVER SECTION
STA 7+00.81 PORTAL FACE
CHUTE AND FLIP BUCKET
STA 7+59.37
TUNNEL CONSTRUCTION PAD
STA 7+11.33 ELEV 3358.77
STA 7+45.39 INV ELEV 3355.0 BUCKET INVERT
1
STA 7+57.87 INV ELEV 3358.5 BUCKET LIP
STA 7+89.37 TOP OF SLAB ELEV 3342.0
SCOUR SLAB
3.5
1
3
1
3324.4
1 VERTICAL CURVE AND FLIP BUCKET- SHT S-71 FOR INVERT PROFILE ELEVATIONS
3500
3450
3400
3350
3300
3250
3200
-1+50
-1+00
-0+50
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
5+50
6+00
6+50
7+00
7+50
8+00
8+50
9+00
9+50
10+00

APPROVED FOR CONSTRUCTION

PROFILE

SCALE: 1"=40'

NO	BY	DATE	REVISION DESCRIPTION
1			CHANGE NOTE, ADDENDUM #3, ITEM 17

MAK	SM	WRK
DRAWN	DESIGNED	CHECKED
WRK	7/97	141.9501
APPROVED	DATE	PROJECT NO

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

PRIMARY OUTLET WORKS
PLAN AND PROFILE

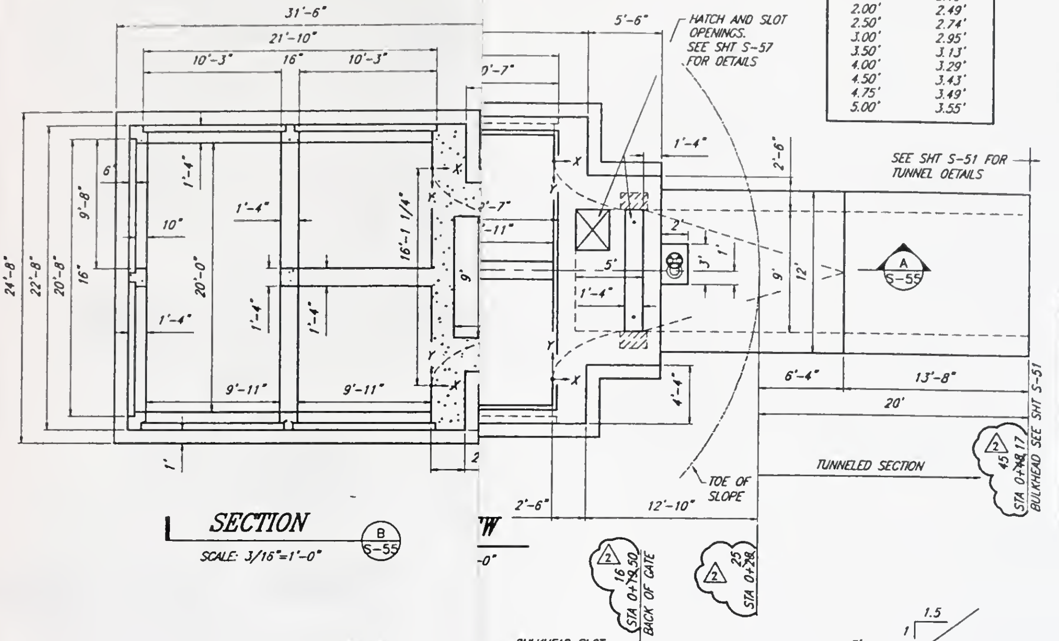
J7

SHEET
C-16

TAILS. SEE SHTS S-56, S-57, S-58
BLE FILL CONCRETE, TO UNDISTURBED ROCK,
E INTAKE STRUCTURE BELOW ELEV 3370.
E (TUNNEL PORTAL)
2

TABLE OF ENTRANCE CURVE VALUES

X	Y
0.00'	0.00'
0.50'	1.30'
1.00'	1.81'
1.50'	2.19'
2.00'	2.49'
2.50'	2.74'
3.00'	2.95'
3.50'	3.13'
4.00'	3.29'
4.50'	3.43'
4.75'	3.49'
5.00'	3.55'

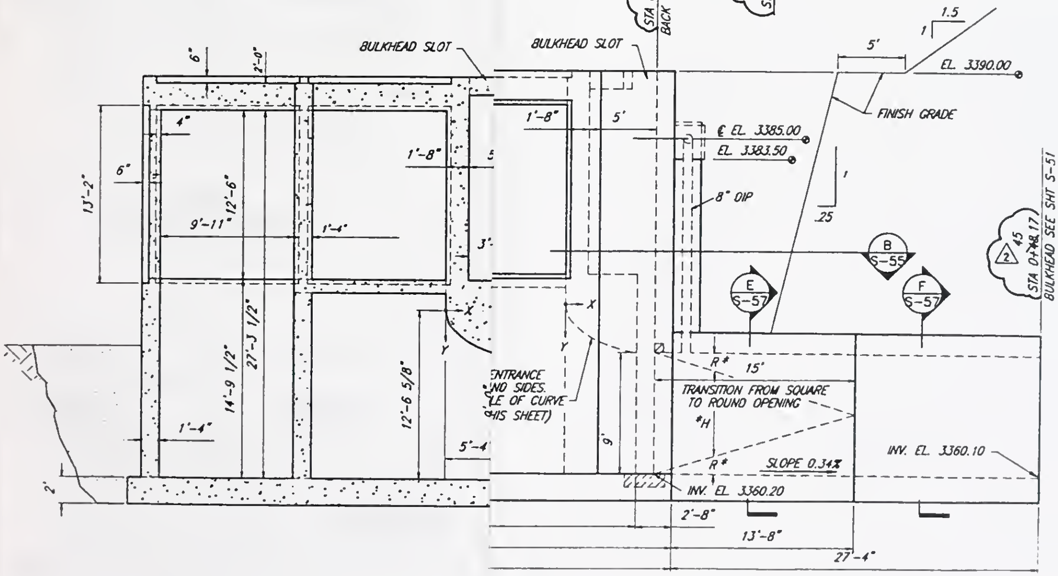


SECTION B S-55

SCALE: 3/16"=1'-0"

W

-0"



* SEE TRANSITION DATA TABLE ON SHT S-56

SECTION A S-55

SCALE: 3/16"=1'-0"

VIEW

"=1'-0"

NO	BY	DATE	REVISION DESCRIPTION
2			CHANGED STATION CALLOUTS, ADDENDUM #4, ITEM 23
1			REVISED AND REISSUED PER ADDENDUM #1, ITEM 31

DWG 134-333

INTAKE STRUCTURE
PLAN AND SECTIONS

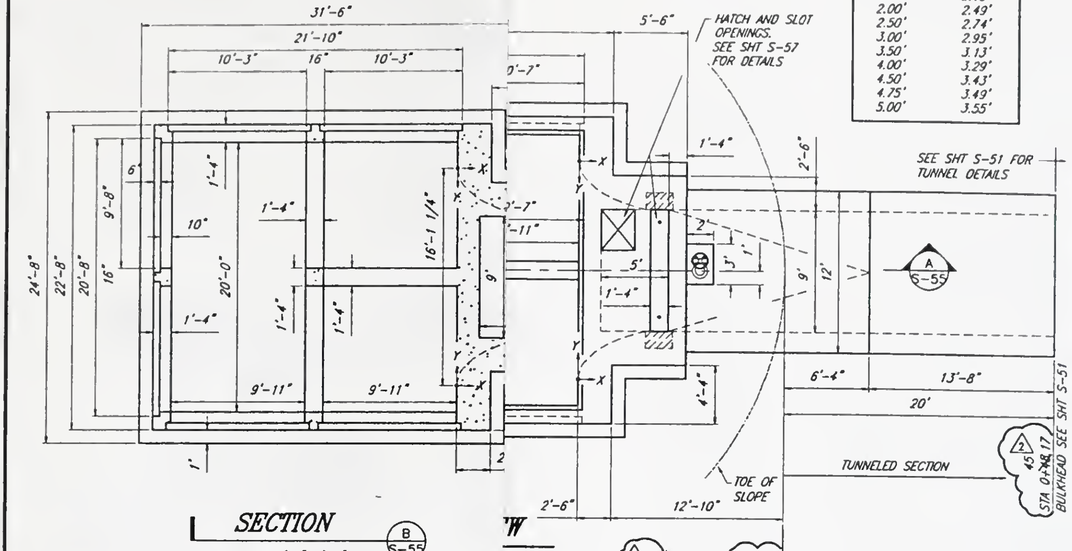
J9

SHEET
S-55

TAILS, SEE SHTS S-56, S-57, S-58
BLE FILL CONCRETE, TO UNDISTURBED ROCK,
E INTAKE STRUCTURE BELOW ELEV 3370.
E (TUNNEL PORTAL)

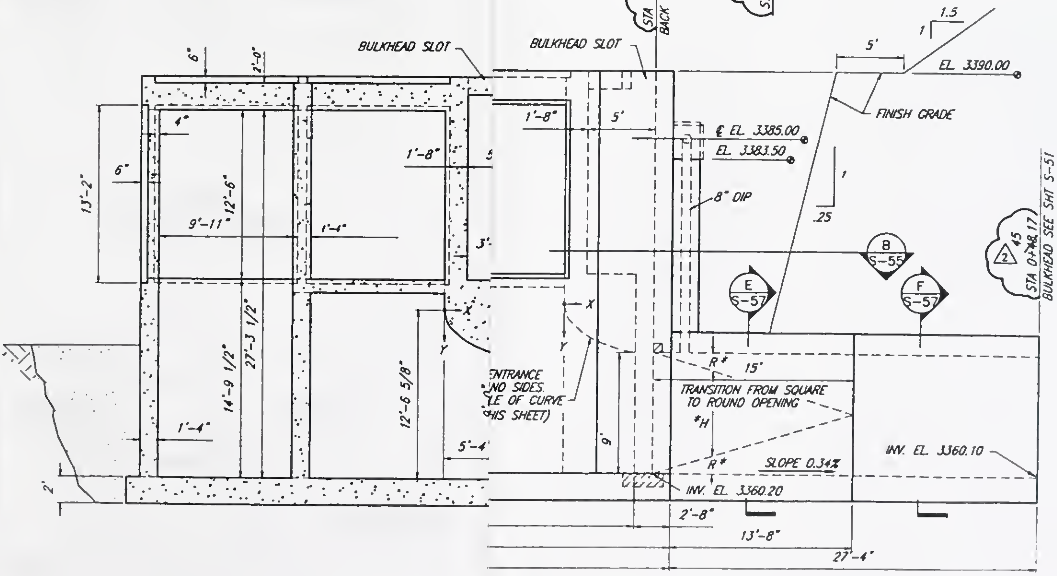
TABLE OF ENTRANCE CURVE VALUES

X	Y
0.00'	0.00'
0.50'	1.30'
1.00'	1.81'
1.50'	2.19'
2.00'	2.49'
2.50'	2.74'
3.00'	2.95'
3.50'	3.13'
4.00'	3.29'
4.50'	3.43'
4.75'	3.49'
5.00'	3.55'



SECTION (B S-55)
SCALE: 3/16"=1'-0"

EW
-0"



* SEE TRANSITION DATA TABLE ON SHT S-56

SECTION (A S-55)
SCALE: 3/16"=1'-0"

VIEW
"=1'-0"

NO	BY	DATE	REVISION DESCRIPTION
2			CHANGED STATION CALLOUTS, ADDENDUM #4, ITEM 23
1			REVISED AND REISSUED PER ADDENDUM #1, ITEM 31

INTAKE STRUCTURE
PLAN AND SECTIONS

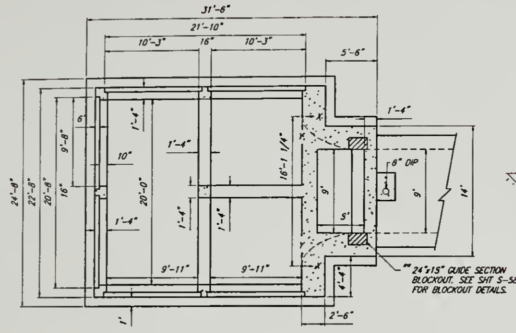
J9

SHEET
S-55

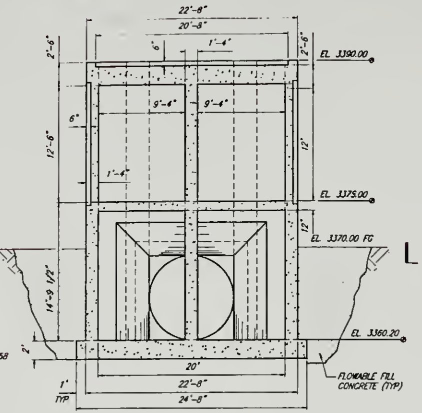
NOTES
1) FOR REINFORCING DETAILS, SEE SHTS S-56, S-57, S-58
2) BACKFILL WITH FLOWABLE FILL CONCRETE, TO UNDISTURBED ROCK. ALL EXCAVATION AT THE INTAKE STRUCTURE BELOW ELEV 3370 EXTEND TO STA 0+25± (TUNNEL PORTAL)

TABLE OF ENTRANCE CURVE VALUES

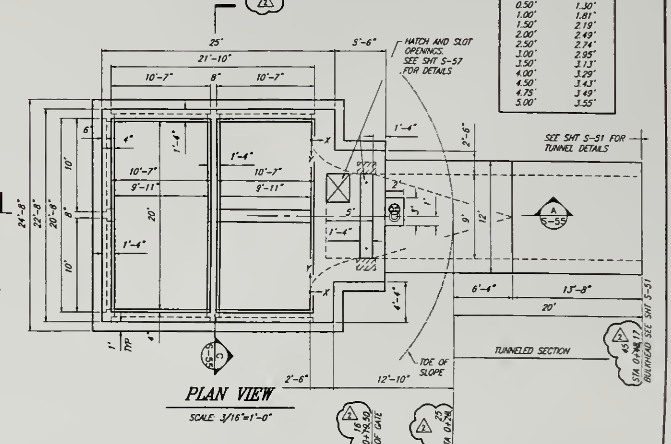
X	Y
0.00'	0.00'
0.50'	1.30'
1.00'	1.81'
1.50'	2.19'
2.00'	2.49'
2.50'	2.74'
3.00'	2.95'
3.50'	3.13'
4.00'	3.29'
4.50'	3.43'
4.75'	3.49'
5.00'	3.55'



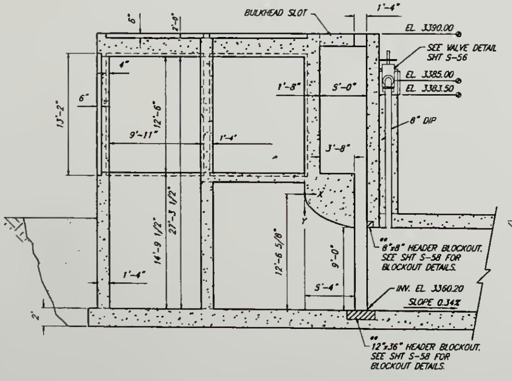
SECTION B S-55
SCALE: 3/16"=1'-0"



SECTION C S-55
SCALE: 3/16"=1'-0"

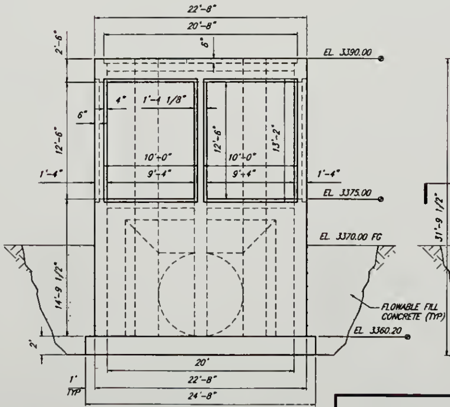


PLAN VIEW
SCALE: 3/16"=1'-0"


BULKHEAD SLOT
1'-4"
EL 3390.00
SEE VALVE DETAIL SHT S-56
EL 3385.00
EL 3383.50
8" DIP
13'-2"
9'-11"
12'-6"
27'-3 1/2"
14'-9 1/2"
** 8"x8" HEADER BLOCKOUT. SEE SHT S-58 FOR BLOCKOUT DETAILS.
INV. EL 3360.20
SLOPE 0.34%
** 12"x36" HEADER BLOCKOUT. SEE SHT S-58 FOR BLOCKOUT DETAILS.

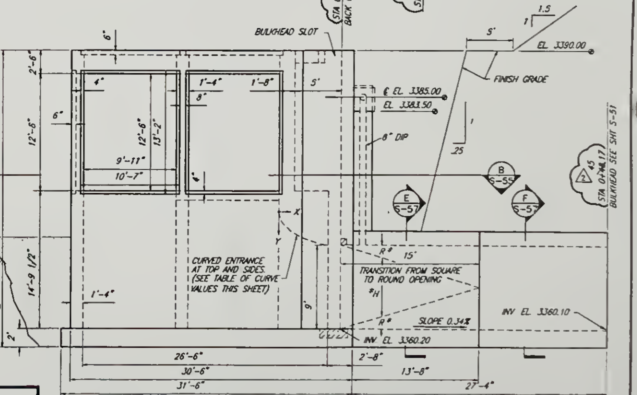
SECTION A S-55
SCALE: 3/16"=1'-0"

** BULKHEAD BLOCKOUT REQUIREMENTS TO BE COORDINATED WITH MANUFACTURER DURING SHOP DRAWING PROCESS.



FRONT VIEW
SCALE: 3/16"=1'-0"

APPROVED FOR CONSTRUCTION



SIDE VIEW
SCALE: 3/16"=1'-0"

* SEE TRANSITION DATA TABLE ON SHT S-56

NO	BY	DATE	REVISION DESCRIPTION
2			CHANGED STATION CALLOUTS, ADDENDUM #4, ITEM 23
1			REVISED AND REISSUED PER ADDENDUM #1, ITEM 31

DRAWN	DESIGNED	CHECKED
KRW	JR	DS
APPROVED	**DATE**	**PROJECT NO**
BK	JULY 97	141.9501

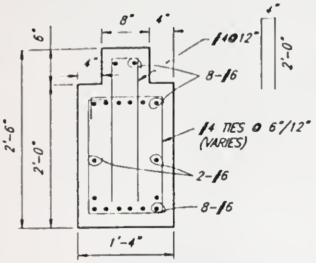
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

INTAKE STRUCTURE
PLAN AND SECTIONS

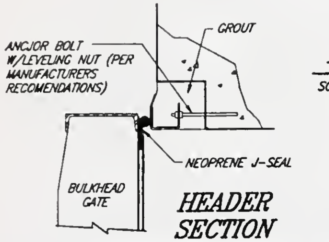
J9

SHEET
S-55

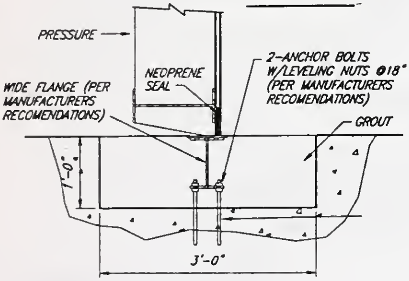


DETAIL 1

SCALE: 1" = 1'-0"

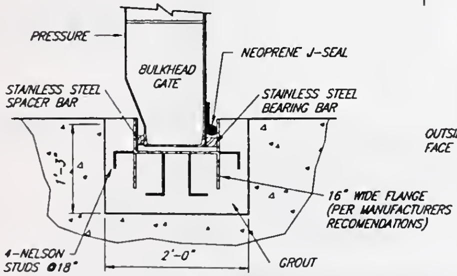

GROUT
ANCJOR BOLT W/LEVELING NUT (PER MANUFACTURERS RECOMENDATIONS)
NEOPRENE J-SEAL
BULKHEAD GATE

HEADER SECTION


PRESSURE
NEOPRENE SEAL
2-ANCHOR BOLTS W/LEVELING NUTS @18" (PER MANUFACTURERS RECOMENDATIONS)
WIDE FLANGE (PER MANUFACTURERS RECOMENDATIONS)
GROUT
1'-0"
3'-0"

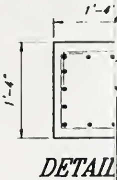
SLAB INVERT SECTION

SCALE: 1" = 1'-0"


PRESSURE
NEOPRENE J-SEAL
BULKHEAD GATE
STAINLESS STEEL SPACER BAR
STAINLESS STEEL BEARING BAR
1'-3"
16" WIDE FLANGE (PER MANUFACTURERS RECOMENDATIONS)
4-NELSON STUDS @18"
2'-0"
GROUT

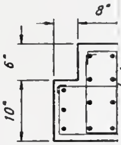
SIDE WALL GUIDE SECTION

SCALE: 1" = 1'-0"



DETAIL

SCALE: 1" = 1

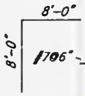


DETAIL

SCALE: 1" = 1

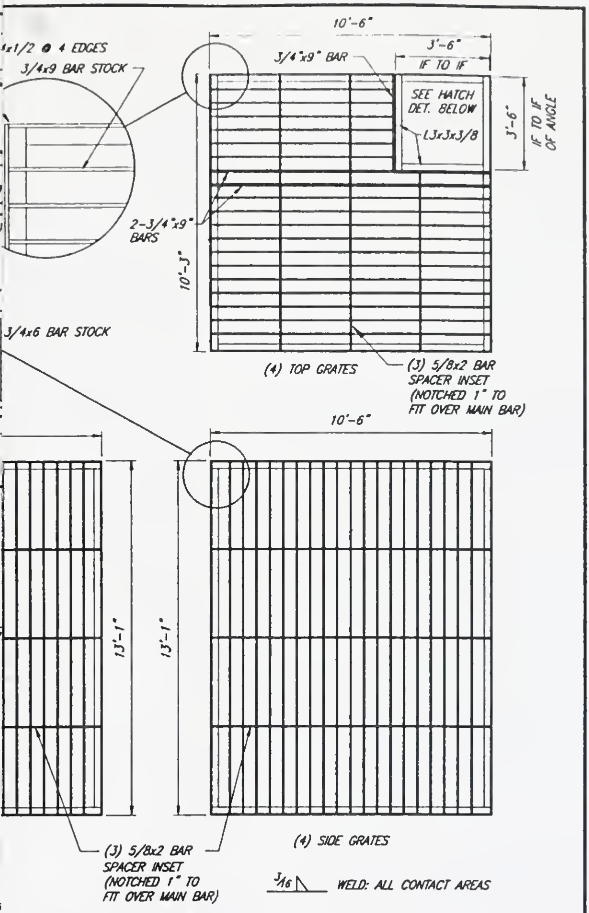
L6x4x3/8
NELSON S

GR



OUTSIDE FACE

#5



GRATING DETAILS

SCALE: 3/8" = 1'-0"

GENERAL NOTES:

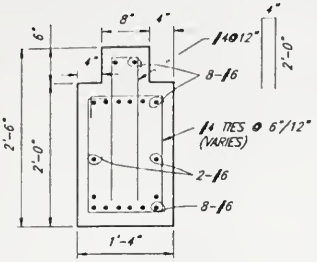
1. CONTINUE EVERY OTHER BAR FOR 28" UP INTO DETAIL 3 BEAM (SEE DETAIL 4 & 5)
2. CONTINUE EVERY OTHER BAR 22" UP INTO DETAIL 1 BEAM. (SEE DETAIL 2)
3. ALL CONSTRUCTION JOINTS SHALL BE SANDBLASTED TO EXPOSE COARSE AGGREGATE AND PRODUCE A MINIMUM 1/4" AMPLITUDE SURFACE VARIATION.
4. 2" CONCRETE COVER REQUIRED OVER ALL REINFORCING STEEL.
5. BEVEL ALL OUTSIDE CONCRETE CORNERS WITH 3/4"x3/4" CHAMFER STRIPS.
6. GRATING DIMENSIONS SHALL BE CONFIRMED IN THE FIELD BY THE CONTRACTOR TO ASSURE A PROPER FIT.
7. ALL GRATING SHALL BE HOT DIPPED GALVANIZED.
8. BOLTS SIDE AND FRONT GRATING PANELS TO STRUCTURE THROUGH PERIMETER ANGLE STEEL WITH 1/2"x6" SS ANCHOR BOLTS AT 24" ON CENTER.

NO	BY	DATE	REVISION DESCRIPTION

INLET STRUCTURE
REINFORCING AND GRATING DETAILS

J11

SHEET
S-58

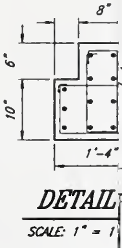


DETAIL 1

SCALE: 1" = 1'-0"

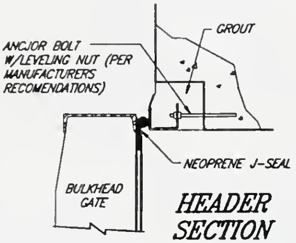
DETAIL

SCALE: 1" = 1

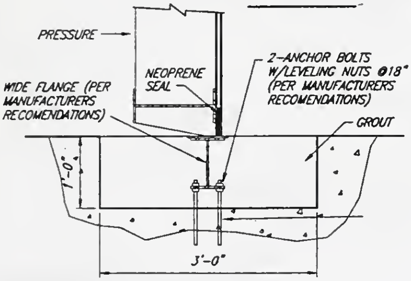


DETAIL

SCALE: 1" = 1

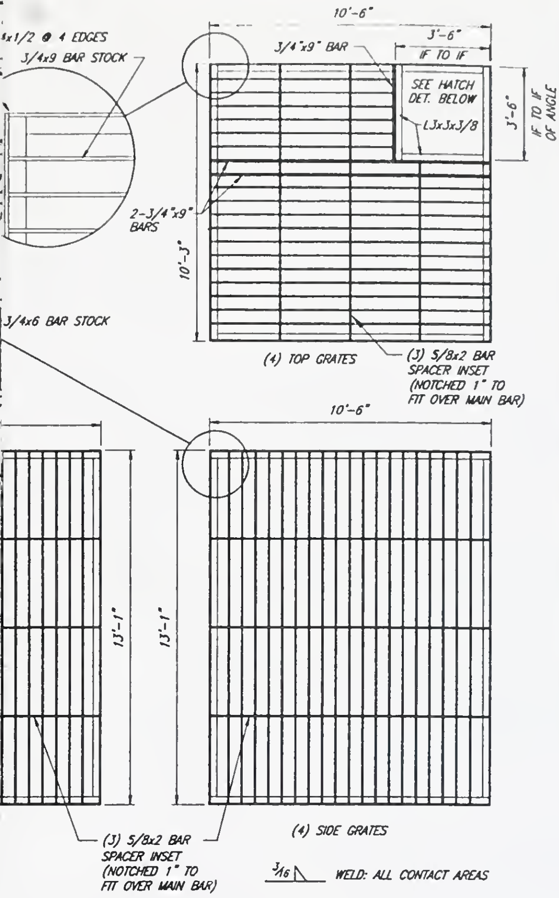

GROUT
ANCJOR BOLT W/LEVELING NUT (PER MANUFACTURERS RECOMENDATIONS)
NEOPRENE J-SEAL
BULKHEAD GATE

HEADER SECTION


PRESSURE
NEOPRENE SEAL
WIDE FLANGE (PER MANUFACTURERS RECOMENDATIONS)
2-ANCHOR BOLTS W/LEVELING NUTS @18" (PER MANUFACTURERS RECOMENDATIONS)
GROUT
1'-0"
3'-0"

SLAB INVERT SECTION

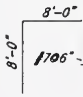
SCALE: 1" = 1'-0"



GR

GRATING DETAILS

SCALE: 3/8" = 1'-0"

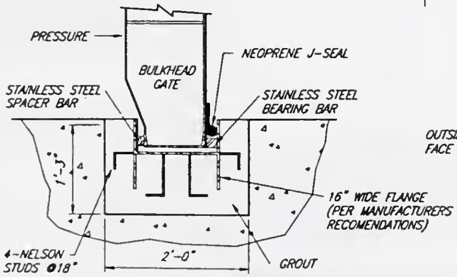


GENERAL NOTES:

1. CONTINUE EVERY OTHER BAR FOR 28" UP INTO DETAIL 3 BEAM (SEE DETAIL 4 & 5)
2. CONTINUE EVERY OTHER BAR 22" UP INTO DETAIL 1 BEAM. (SEE DETAIL 2)
3. ALL CONSTRUCTION JOINTS SHALL BE SANDBLASTED TO EXPOSE COARSE AGGREGATE AND PRODUCE A MINIMUM 1/4" AMPLITUDE SURFACE VARIATION.
4. 2" CONCRETE COVER REQUIRED OVER ALL REINFORCING STEEL.
5. BEVEL ALL OUTSIDE CONCRETE CORNERS WITH 3/4"x3/4" CHAMFER STRIPS.
6. GRATING DIMENSIONS SHALL BE CONFIRMED IN THE FIELD BY THE CONTRACTOR TO ASSURE A PROPER FIT.
7. ALL GRATING SHALL BE HOT DIPPED GALVANIZED.
8. BOLTS SIDE AND FRONT GRATING PANELS TO STRUCTURE THROUGH PERIMETER ANGLE STEEL WITH 1/2"x6" SS ANCHOR BOLTS AT 24" ON CENTER.

OUTSIDE FACE

#5


PRESSURE
BULKHEAD GATE
NEOPRENE J-SEAL
STAINLESS STEEL SPACER BAR
STAINLESS STEEL BEARING BAR
1'-3"
16" WIDE FLANGE (PER MANUFACTURERS RECOMENDATIONS)
4-NELSON STUDS @18"
2'-0"
GROUT

SIDE WALL GUIDE SECTION

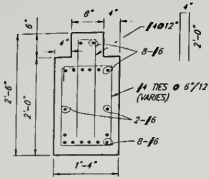
SCALE: 1" = 1'-0"

NO	BY	DATE	REVISION DESCRIPTION

INLET STRUCTURE
REINFORCING AND GRATING DETAILS

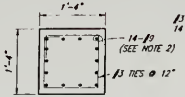
J11

SHEET
S-58



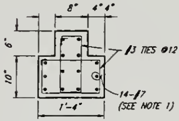
DETAIL 1

SCALE: 1" = 1'-0"



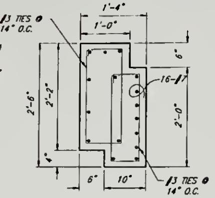
DETAIL 2

SCALE: 1" = 1'-0"



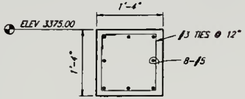
DETAIL 4

SCALE: 1" = 1'-0"



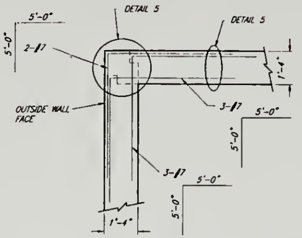
DETAIL 3

SCALE: 1" = 1'-0"



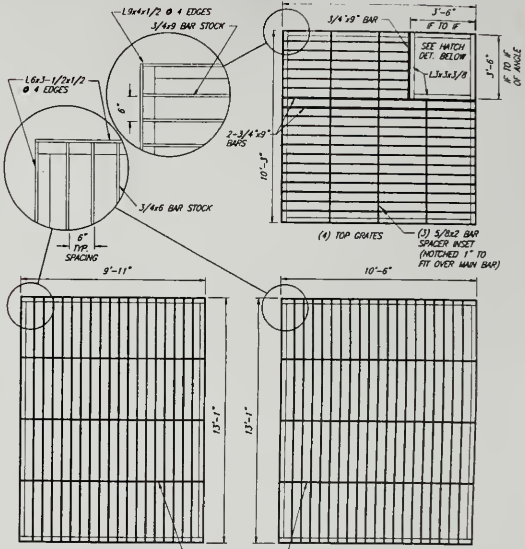
DETAIL 6

SCALE: 1" = 1'-0"



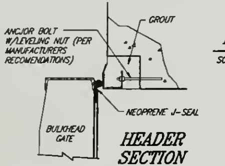
CORNER PLAN VIEW OF TOP BEAMS

ADDITIONAL REINFORCING FOR CORNERS OF DETAIL 3 BEAMS
(TYPICAL AT ALL 4 CORNERS)
SCALE: 1/2" = 1'-0"

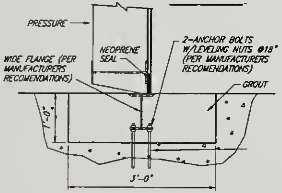


GRATING DETAILS

SCALE: 3/8" = 1'-0"

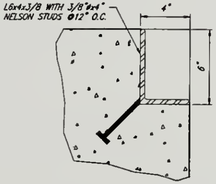

GROUT
ANCJOR BOLT W/LEVELING NUT (PER MANUFACTURERS RECOMENDATIONS)
NEOPRENE J-SEAL
BULKHEAD GATE

HEADER SECTION


PRESSURE
NEOPRENE SEAL
2-ANCHOR BOLTS W/LEVELING NUTS @18" (PER MANUFACTURERS RECOMENDATIONS)
WIDE FLANGE (PER MANUFACTURERS RECOMENDATIONS)
GROUT
1'-0"
3'-0"

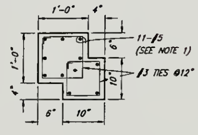
SLAB INVERT SECTION

SCALE: 1" = 1'-0"



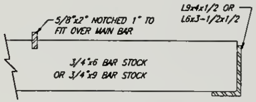
GRATING CHANNEL DETAIL

SCALE: 3" = 1'-0"



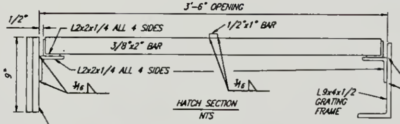
DETAIL 5

SCALE: 1" = 1'-0"

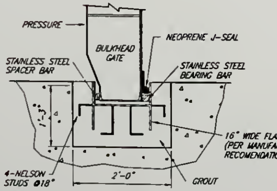

5/8"x2" NOTCHED 1" TO FIT OVER MAIN BAR
L9x4x1/2 OR L6x3-1/2x1/2
3/4"x6 BAR STOCK OR 3/4"x9 BAR STOCK

GRATING SECTION DETAIL

NTS

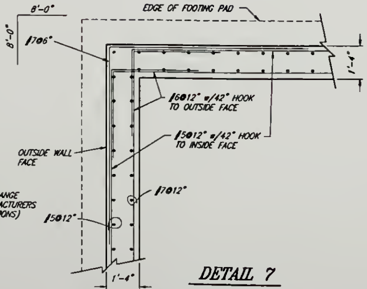


HATCH SECTION
NTS


PRESSURE
BULKHEAD GATE
NEOPRENE J-SEAL
STAINLESS STEEL SPACER BAR
STAINLESS STEEL BEARING BAR
1'-3"
16" WIDE FLANGE (PER MANUFACTURERS RECOMENDATIONS)
4-NELSON STUDS @18"
2'-0"
GROUT

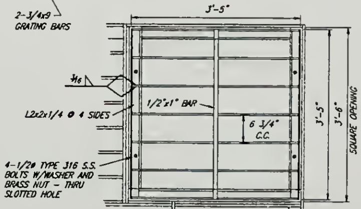
SIDE WALL GUIDE SECTION

SCALE: 1" = 1'-0"



DETAIL 7

SCALE: 1/2" = 1'-0"



INLET GRATING HATCH

SCALE. 1"=1'-0"

APPROVED FOR
CONSTRUCTION

GENERAL NOTES:

1. CONTINUE EVERY OTHER BAR FOR 28" UP INTO DETAIL 3 BEAM (SEE DETAIL 4 & 5)
2. CONTINUE EVERY OTHER BAR 22" UP INTO DETAIL 1 BEAM. (SEE DETAIL 2)
3. ALL CONSTRUCTION JOINTS SHALL BE SANDBLASTED TO EXPOSE COARSE AGGREGATE AND PRODUCE A MINIMUM 1/4" AMPLITUDE SURFACE VARIATION.
4. 2" CONCRETE COVER REQUIRED OVER ALL REINFORCING STEEL
5. BEVEL ALL OUTSIDE CONCRETE CORNERS WITH 3/4"x3/4" CHAMFER STRIPS.
6. GRATING DIMENSIONS SHALL BE CONFIRMED IN THE FIELD BY THE CONTRACTOR TO ASSURE A PROPER FIT.
7. ALL GRATING SHALL BE HOT DIPPED GALVANIZED.
8. BOLTS SIDE AND FRONT GRATING PANELS TO STRUCTURE THROUGH PERIMETER ANGLE STEEL WITH 1/2"x6" SS ANCHOR BOLTS AT 24" ON CENTER.

NO	BY	DATE	REVISION DESCRIPTION

KRW DRAWN	JR DESIGNED	DS CHECKED
BK APPROVED	04/14/97 DATE	141 9501 PROJECT NO.

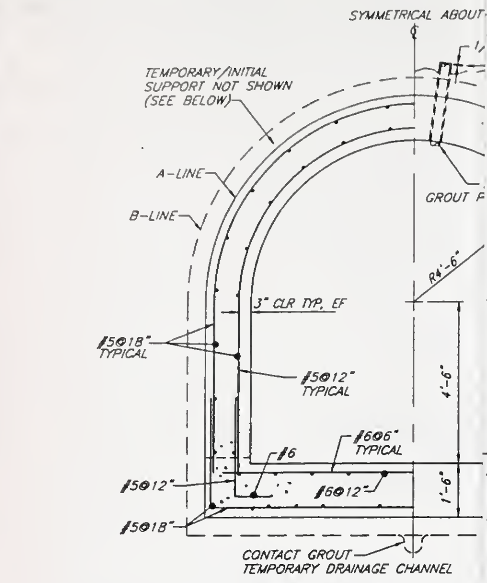
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
216 East Mendenhall, Suite C-1, Bozeman MT. 59715

INLET STRUCTURE
REINFORCING AND GRATING DETAILS

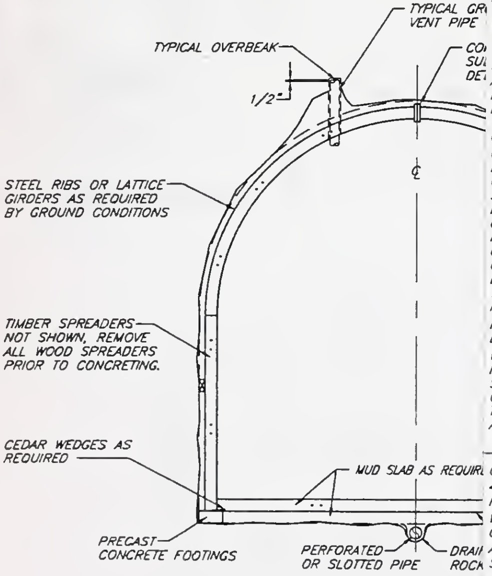
J11

SHEET
S-58



TYPICAL DOWNSTEAM TUNNE

SCALE: 1/2" = 1'


TYPICAL GR
VENT PIPE
TYPICAL OVERBEAK
CO
SU
DE
1/2"
℄
STEEL RIBS OR LATTICE GIRDERS AS REQUIRED BY GROUND CONDITIONS
TIMBER SPREADERS NOT SHOWN, REMOVE ALL WOOD SPREADERS PRIOR TO CONCRETING.
CEDAR WEDGES AS REQUIRED
MUD SLAB AS REQUIR
PRECAST CONCRETE FOOTINGS
PERFORATED OR SLOTTED PIPE
DRAI
ROCK

RIBS AND LAGGING

NO SCALE

GENERAL NOTES ON EXCAVATION AND SUPPORT METHODS

ALL TUNNEL WORK SHALL BE PERFORMED IN ACCORDANCE WITH THE PLANS AND THE SPECIFICATIONS AND THE FOLLOWING NOTES.

THE WORK SHALL BE PROPERLY LIGHTED, VENTILATED, AND DRAINED DURING CONSTRUCTION.

THE EXCAVATION AND TEMPORARY SUPPORT METHODS ARE TO BE DESIGNED BY THE CONTRACTOR'S ENGINEER. THE CONTRACTOR'S ENGINEER SHALL BE A REGISTERED ENGINEER WITH PREVIOUS EXPERIENCE IN TUNNEL DESIGN.

THE TUNNEL SHALL BE DRIVEN BY ONE OR A COMBINATION OF THE FOLLOWING METHODS: DRILL AND BLAST HAND MINING METHODS, SPADERS, SMALL BACKHOE, ROAD HEADER, OR SMALL MUCKER, AND LOW PROFILE LOAD HAUL DUMP VEHICLES, OR ANY OTHER PROVEN METHOD PROVIDED THE WORK OF DRIVING IS CARRIED ON CONTINUOUSLY, WITHIN THE LIMITATIONS OF THE SPECIFICATIONS, UNTIL COMPLETION OF WORK.

INITIAL (OR PRIMARY, OR TEMPORARY) SUPPORT SHALL BE INSTALLED IN ORDER TO PREVENT EXCESSIVE LOSS OF GROUND. BECAUSE OF THE POSSIBILITY OF IRREGULAR EXCAVATED TUNNEL SURFACES, PROVISIONS ARE MADE FOR DEALING WITH OVERBREAKS BY CONTACT GROUTING.

THE CONTRACTOR SHALL UTILIZE THE SUPPORT METHOD THAT IS MOST SUITABLE FOR HIS METHOD OF EXCAVATION, OPERATIONS AND EQUIPMENT, AND THE TYPE OF GROUND BEING EXCAVATED.
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NOTES ON TUNNEL SUPPORTS

ALL MATERIALS USED IN THE TUNNEL FOR TEMPORARY SUPPORT SHALL BE COMPATIBLE WITH FINAL LINING AND ARE SUBJECT TO THE REVIEW OF THE ENGINEER.

REMOVE LOOSE UNSAFE GROUND/STRATA BEFORE INSTALLATION OR ERECTION OF SUPPORT BY BARRING, PRYING OR OTHER METHODS WHICH WILL NOT FURTHER DETERIORATE THE IN-SITU MATERIAL.

SHOTCRETE SHALL BE USED AS LAGGING BETWEEN SETS.

TYPICAL APPLICATIONS OF THE VARIOUS INITIAL SUPPORTING METHODS ARE INFORMATIONAL ONLY. THE CONTRACTOR MAY SUBMIT ALTERNATIVE INITIAL SUPPORT SYSTEM(S).

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GROUND WATER WILL BE ENCOUNTERED DURING TUNNELING. WATER MAY ALSO BE PRESENT FROM CONTRACTOR'S OPERATIONS; i.e. FROM WATERLINE BREAKS, LEAKY HOSES USED FOR DUST CONTROL, ETC. WATER ON INVERT CAN MAKE WORKING CONDITIONS DIFFICULT. THEREFORE EVERY EFFORT SHALL BE MADE TO AVOID STANDING WATER EITHER CREATED FROM CONTRACTOR OPERATIONS OR FROM OCCASIONAL INFLOWS OF GROUND WATER. CONTRACTOR IS TO INSTALL AND MAINTAIN TEMPORARY DRAINAGE FACILITIES OF ADEQUATE SIZE, INCLUDING STANDBY PUMPS FOR EMERGENCY USE, TO COLLECT AND DISPOSE OF WATER WHICH ENTERS THE UNDERGROUND EXCAVATIONS. WATER SHALL NOT BE PERMITTED TO STAND AT THE TUNNEL FACE, ON THE INVERT, OR IN WORKING AREAS.

CONSTRUCTION TRAFFIC, DEPENDING ON MACHINERY USED FOR EXCAVATION, MAY AFFECT THE INTEGRITY OF THE INVERT. FOR CONSTRUCTION TRAFFICABILITY, THE CONSTRUCTION OPERATIONS AND SEQUENCES SHALL BE PLANNED AND IMPLEMENTED TO AVOID EXCESSIVE DAMAGE TO THE EXCAVATED FLOOR OF TUNNEL. WHERE THE NATURAL GROUND CONDITIONS ARE SUCH THAT INVERT PROTECTION IS NECESSARY TO PREVENT RUTTING, TUNNEL INVERT PROTECTION CONSISTING OF EITHER GRAVEL BLANKET OR PRECAST OR POURED CONCRETE WORK SLAB AS APPROVED BY ENGINEER, SHALL BE PLACED. DRAIN ROCK MAY BE LEFT IN PLACE PROVIDED IT IS CONTACT GROUTED. THIS WORK MAY BE PERFORMED ON WEEKENDS, IF APPROPRIATE FOR METHOD OF TUNNEL EXCAVATION.

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STRUCTURAL NOTES

CONCRETE SHALL BE NORMAL WEIGHT CONCRETE AND HAVE A MINIMUM 28 DAY COMPRESSIVE STRENGTH (f'c) OF 4000 PSI.

REINFORCING STEEL SHALL CONFORM TO ASTM A615 GRADE 60 (fy=60ksi).

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ALL LAP SPLICES SHALL BE CLASS B AND ALL HOOKS SHALL BE STANDARD HOOKS AS DEFINED BY ACI 318.

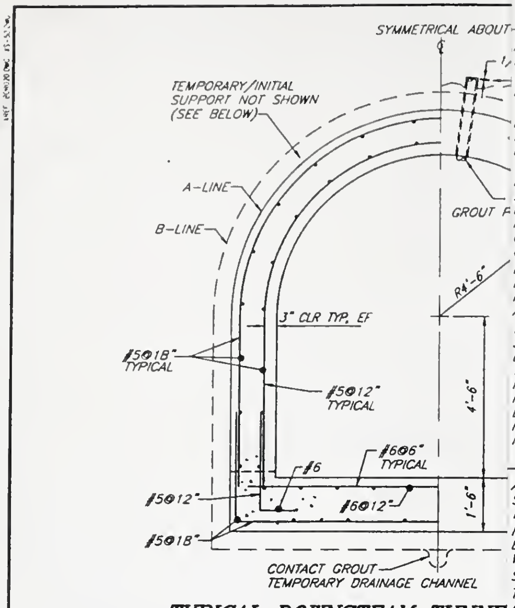
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

PRIMARY OUTLET WORKS
TUNNEL CROSS SECTIONS

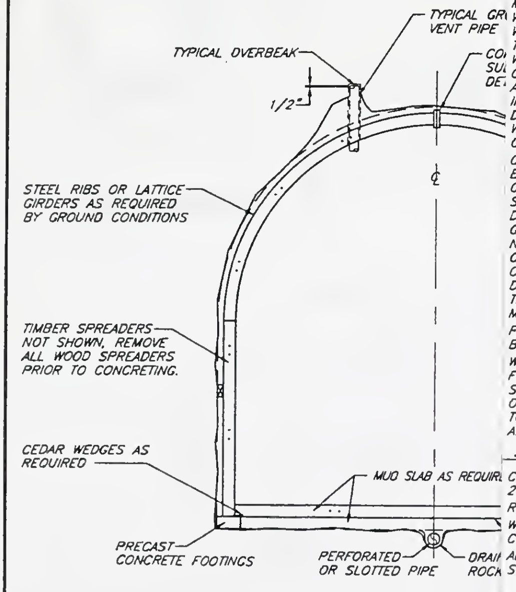
J13

SHEET
S-50



TYPICAL DOWNSTEAM TUNNE

SCALE: 1/2" = 1'


TYPICAL GR
VENT PIPE
TYPICAL OVERBEAK
1/2"
CO
SU
DE
℄
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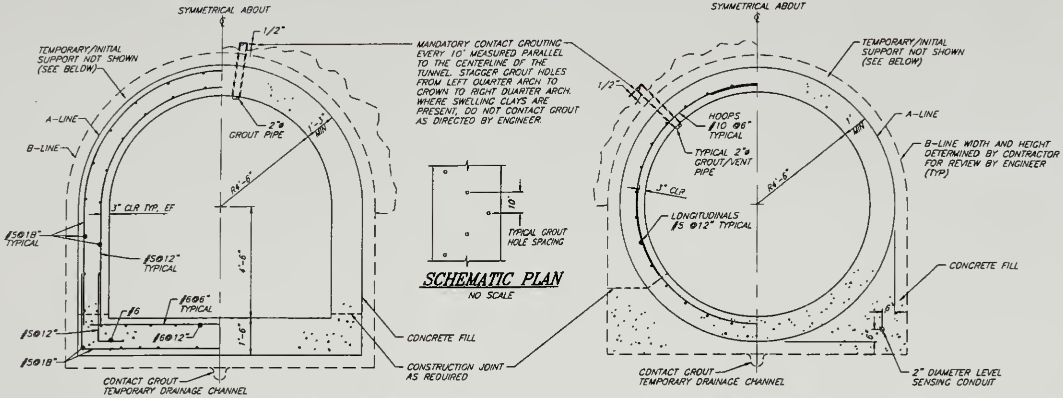
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

PRIMARY OUTLET WORKS
TUNNEL CROSS SECTIONS

J13

SHEET
S-50


SYMMETRICAL ABOUT ℄
1/2"
TEMPORARY/INITIAL SUPPORT NOT SHOWN (SEE BELOW)
A-LINE
B-LINE
MANDATORY CONTACT GROUTING EVERY 10' MEASURED PARALLEL TO THE CENTERLINE OF THE TUNNEL. STAGGER GROUT HOLES FROM LEFT QUARTER ARCH TO CROWN TO RIGHT QUARTER ARCH. WHERE SWELLING CLAYS ARE PRESENT, DO NOT CONTACT GROUT AS DIRECTED BY ENGINEER.
2"ø GROUT PIPE
1'-3" MIN
R4'-6"
3" CLR TYP, EF
#5@18" TYPICAL
#5@12" TYPICAL
4'-6"
#6@6" TYPICAL
#6
#5@12"
#6@12"
1'-6"
#5@18"
CONCRETE FILL
CONSTRUCTION JOINT AS REQUIRED
CONTACT GROUT TEMPORARY DRAINAGE CHANNEL
10'
TYPICAL GROUT HOLE SPACING
SYMMETRICAL ABOUT ℄
1/2"
TEMPORARY/INITIAL SUPPORT NOT SHOWN (SEE BELOW)
HOOPS #10 @6" TYPICAL
TYPICAL 2"ø GROUT/VENT PIPE
A-LINE
1' MIN
B-LINE WIDTH AND HEIGHT DETERMINED BY CONTRACTOR FOR REVIEW BY ENGINEER (TYP)
3" CLR
R4'-6"
LONGITUDINALS #5 @12" TYPICAL
CONCRETE FILL
6"
6"
CONTACT GROUT TEMPORARY DRAINAGE CHANNEL
2" DIAMETER LEVEL SENSING CONDUIT

SCHEMATIC PLAN

NO SCALE

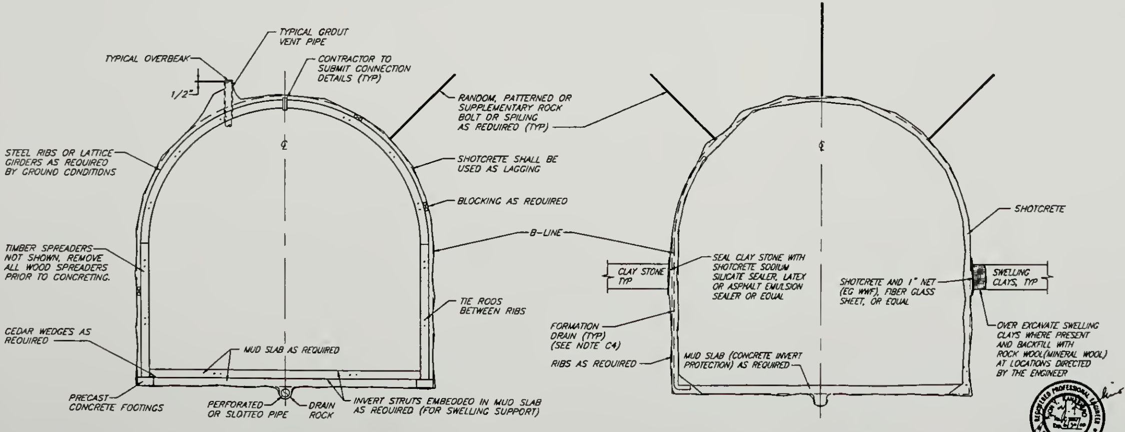
TYPICAL DOWNSTEAM TUNNEL CROSS SECTION

SCALE: 1/2" = 1'

TYPICAL UPSTEAM TUNNEL CROSS SECTION

SCALE: 1/2" = 1'

FINAL TUNNEL CROSS SECTIONS


TYPICAL OVERBEAK
1/2"
TYPICAL GROUT VENT PIPE
CONTRACTOR TO SUBMIT CONNECTION DETAILS (TYP)
℄
RANDOM, PATTERNED OR SUPPLEMENTARY ROCK BOLT OR SPILING AS REQUIRED (TYP)
STEEL RIBS OR LATTICE GIRDERS AS REQUIRED BY GROUND CONDITIONS
SHOTCRETE SHALL BE USED AS LAGGING
BLOCKING AS REQUIRED
B-LINE
TIMBER SPREADERS NOT SHOWN, REMOVE ALL WOOD SPREADERS PRIOR TO CONCRETING.
TIE RODS BETWEEN RIBS
CEDAR WEDGES AS REQUIRED
MUD SLAB AS REQUIRED
PRECAST CONCRETE FOOTINGS
PERFORATED OR SLOTTED PIPE
DRAIN ROCK
INVERT STRUTS EMBEDDED IN MUD SLAB AS REQUIRED (FOR SWELLING SUPPORT)
℄
SHOTCRETE
CLAY STONE TYP
SEAL CLAY STONE WITH SHOTCRETE SODIUM SILICATE SEALER, LATEX OR ASPHALT EMULSION SEALER OR EQUAL
SHOTCRETE AND 1" NET (EG WWF), FIBER GLASS SHEET, OR EQUAL
SWELLING CLAYS, TYP
FORMATION DRAIN (TYP) (SEE NOTE C4)
RIBS AS REQUIRED
MUD SLAB (CONCRETE INVERT PROTECTION) AS REQUIRED
OVER EXCAVATE SWELLING CLAYS WHERE PRESENT AND BACKFILL WITH ROCK WOOL(MINERAL WOOL) AT LOCATIONS DIRECTED BY THE ENGINEER

RIBS AND LAGGING TUNNEL

NO SCALE

SHOTCRETE AND ROCKBOLTS TUNNEL

NO SCALE

TYPICAL TUNNEL INITIAL SUPPORT CROSS SECTIONS

CIVIL

Montana Temporary Permit No. 519
1-28-98

A. GENERAL NOTES ON EXCAVATION AND SUPPORT METHODS

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APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

DRW DRAWN	JYK DESIGNED	RH/CK/SN CHECKED
APPROVED	7/97 DATE	141.9501 PROJECT NO.

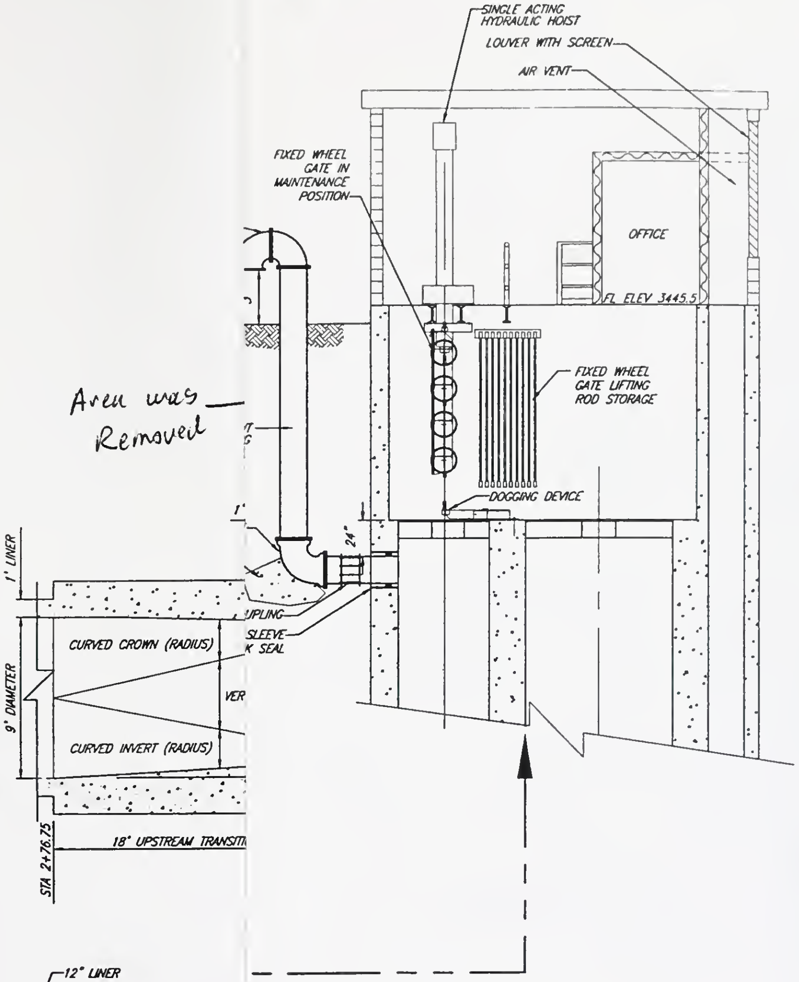
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

PRIMARY OUTLET WORKS
TUNNEL CROSS SECTIONS

J13

SHEET
S-50



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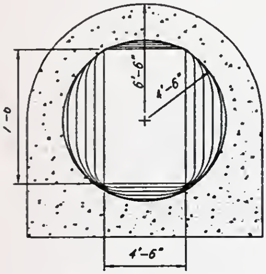
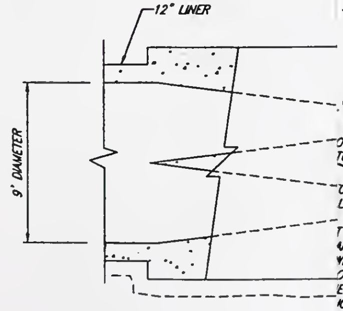


UPSTREAM SECTION

SCALE: 1/4" = 1'-0"



ON SHT S-50 ARE GENERALLY APPLICABLE; HOWEVER, THE
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TRANSITION, THE CONTRACTOR MAY MODIFY THE SHAPE OF
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WEEN STRUCTURE AND ROCK SHALL BE COMPLETED
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OF SILTSTONE SHALL BE FORMED AND RCC
CONCRETE SURFACE.

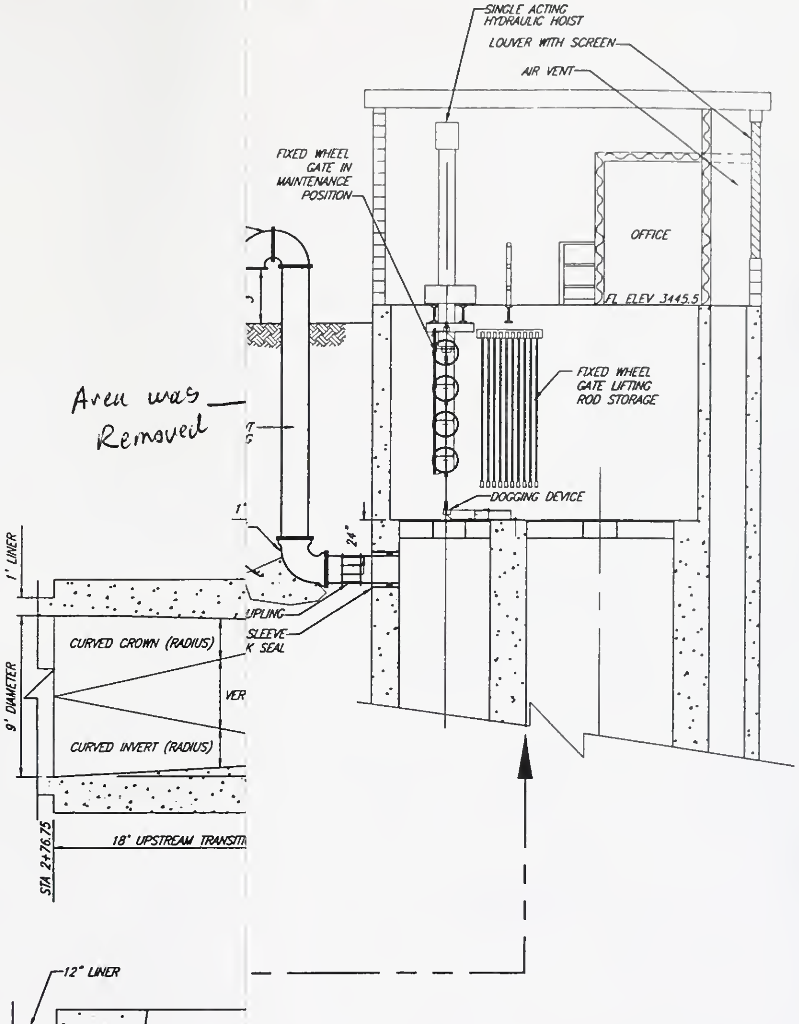
APPROVED FOR
CONSTRUCTION

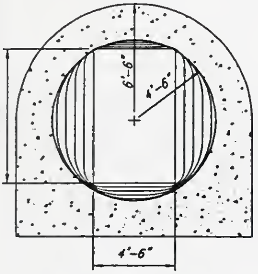
NO	BY	DATE	REVISION DESCRIPTION
1			CHANGED NOTES, ADDENDUM #4, ITEM 17

RY OUTLET WORKS GATE STRUCTURE
PLAN AND SECTIONS

J15

SHEET
C-17





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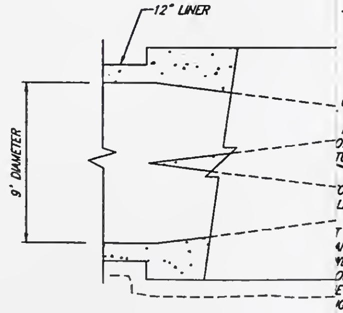

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1			CHANGED NOTES, ADDENDUM #4, ITEM 17

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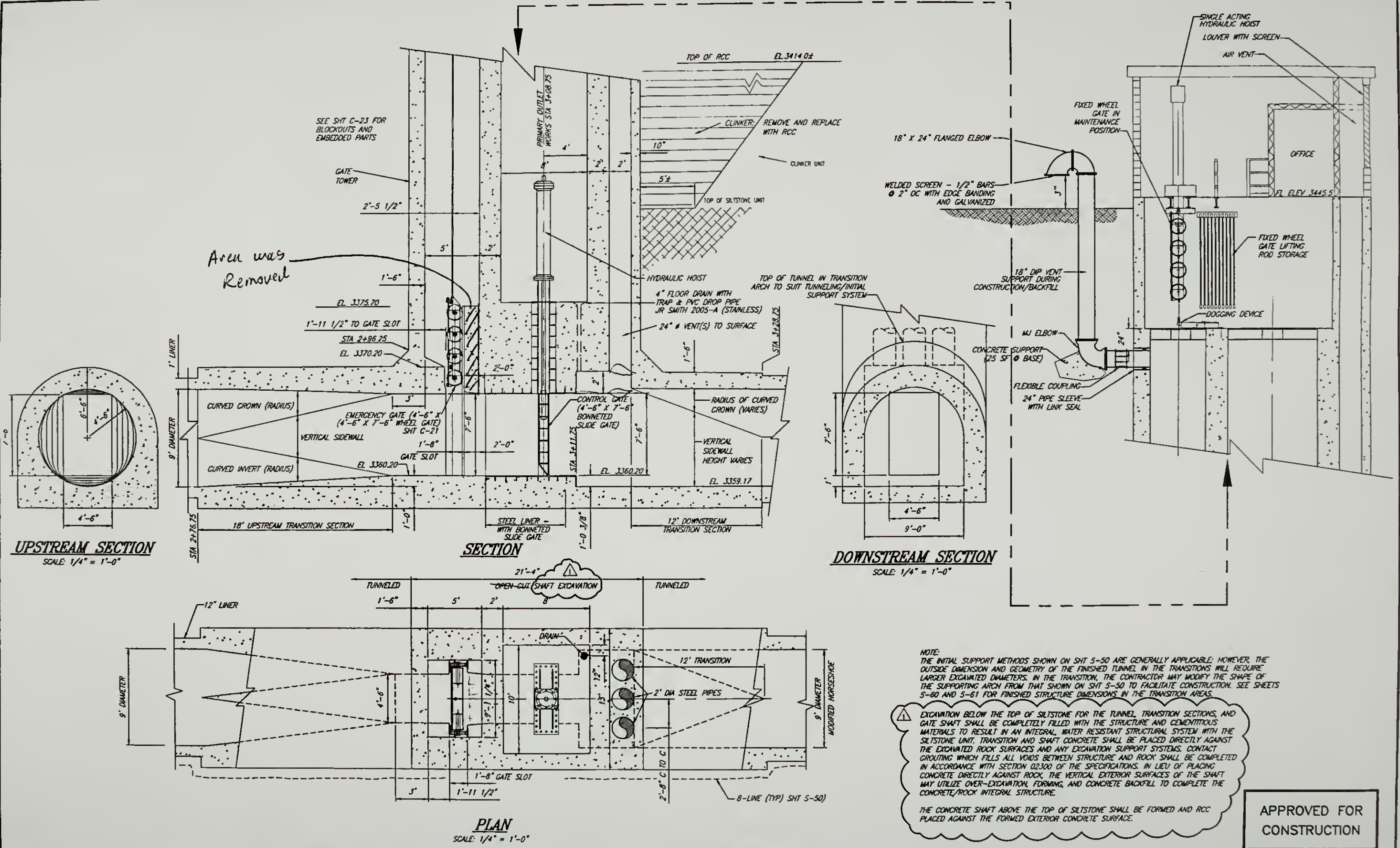
PLAN AND SECTIONS
J15

SHEET
C-17


Area was Removed
SEE SHT C-23 FOR BLOCKOUTS AND EMBEDDED PARTS
GATE TOWER
2'-5 1/2"
PRIMARY OUTLET WORKS STA 3+08.75
TOP OF RCC
EL 3414.0±
CLINKER: REMOVE AND REPLACE WITH RCC
CLINKER UNIT
TOP OF SILTSTONE UNIT
HYDRAULIC HOIST
4" FLOOR DRAIN WITH TRAP & PVC DROP PIPE JR SMITH 2005-A (STAINLESS)
24" ø VENT(S) TO SURFACE
TOP OF TUNNEL IN TRANSITION ARCH TO SUIT TUNNELING/INITIAL SUPPORT SYSTEM
1'-6"
EL 3375.70
1'-11 1/2" TO GATE SLOT
STA 2+96.25
EL 3370.20
1' LINER
STA 3+28.75
CURVED CROWN (RADIUS)
VERTICAL SIDEWALL
CURVED INVERT (RADIUS)
9' DIAMETER
EMERGENCY GATE (4'-6" X (4'-6" X 7'-6" WHEEL GATE) SHT C-21
1'-8"
GATE SLOT
EL 3360.20
CONTROL GATE (4'-6" X 7'-6" BONNETED SLIDE GATE)
STA 3+11.75
EL 3360.20
RADIUS OF CURVED CROWN (VARIES)
VERTICAL SIDEWALL HEIGHT VARIES
EL 3359.17
18' UPSTREAM TRANSITION SECTION
STEEL LINER - WITH BONNETED SLIDE GATE
12' DOWNSTREAM TRANSITION SECTION
STA 2+76.75
1'-0 3/8"
UPSTREAM SECTION
SCALE: 1/4" = 1'-0"
SECTION
DOWNSTREAM SECTION
SCALE: 1/4" = 1'-0"
7'-6"
4'-6"
9'-0"
SINGLE ACTING HYDRAULIC HOIST
LOUVER WITH SCREEN
AIR VENT
FIXED WHEEL GATE IN MAINTENANCE POSITION
OFFICE
18" X 24" FLANGED ELBOW
WELDED SCREEN - 1/2" BARS @ 2" OC WITH EDGE BANDING AND GALVANIZED
FL ELEV 3445.5
FIXED WHEEL GATE LIFTING ROD STORAGE
18" DIP VENT SUPPORT DURING CONSTRUCTION/BACKFILL
DOGGING DEVICE
MJ ELBOW
CONCRETE SUPPORT (25 SF @ BASE)
FLEXIBLE COUPLING
24" PIPE SLEEVE WITH LINK SEAL
21'-4"
TUNNELED
OPEN CUT SHAFT EXCAVATION
TUNNELED
12" LINER
DRAIN
12' TRANSITION
2' DIA STEEL PIPES
9' DIAMETER
9' DIAMETER MODIFIED HORSESHOE
1'-8" GATE SLOT
1'-11 1/2"
2'-8" C TO C
B-LINE (TYP) SHT 5-50
PLAN
SCALE: 1/4" = 1'-0"

NOTE:
THE INITIAL SUPPORT METHODS SHOWN ON SHT 5-50 ARE GENERALLY APPLICABLE; HOWEVER, THE OUTSIDE DIMENSION AND GEOMETRY OF THE FINISHED TUNNEL IN THE TRANSITIONS WILL REQUIRE LARGER EXCAVATED DIAMETERS. IN THE TRANSITION, THE CONTRACTOR MAY MODIFY THE SHAPE OF THE SUPPORTING ARCH FROM THAT SHOWN ON SHT 5-50 TO FACILITATE CONSTRUCTION. SEE SHEETS 5-60 AND 5-61 FOR FINISHED STRUCTURE DIMENSIONS IN THE TRANSITION AREAS.

△1 EXCAVATION BELOW THE TOP OF SILTSTONE FOR THE TUNNEL, TRANSITION SECTIONS, AND GATE SHAFT SHALL BE COMPLETELY FILLED WITH THE STRUCTURE AND CEMENTITIOUS MATERIALS TO RESULT IN AN INTEGRAL, WATER RESISTANT STRUCTURAL SYSTEM WITH THE SILTSTONE UNIT. TRANSITION AND SHAFT CONCRETE SHALL BE PLACED DIRECTLY AGAINST THE EXCAVATED ROCK SURFACES AND ANY EXCAVATION SUPPORT SYSTEMS. CONTACT GROUTING WHICH FILLS ALL VOIDS BETWEEN STRUCTURE AND ROCK SHALL BE COMPLETED IN ACCORDANCE WITH SECTION 02300 OF THE SPECIFICATIONS. IN LIEU OF PLACING CONCRETE DIRECTLY AGAINST ROCK, THE VERTICAL EXTERIOR SURFACES OF THE SHAFT MAY UTILIZE OVER-EXCAVATION, FORMING, AND CONCRETE BACKFILL TO COMPLETE THE CONCRETE/ROCK INTEGRAL STRUCTURE.

THE CONCRETE SHAFT ABOVE THE TOP OF SILTSTONE SHALL BE FORMED AND RCC PLACED AGAINST THE FORMED EXTERIOR CONCRETE SURFACE.

APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
1			CHANGED NOTES, ADDENDUM #4, ITEM 17

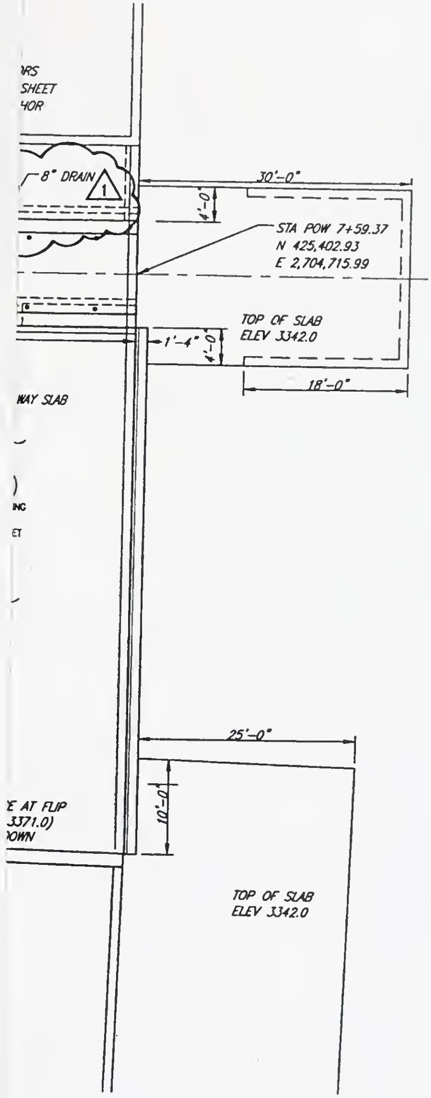
MAX DRAWN	WRK DESIGNED	CHECKED
WRK APPROVED	7/97 DATE	141.9501 PROJECT NO

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

PRIMARY OUTLET WORKS GATE STRUCTURE
PLAN AND SECTIONS
J15

SHEET
C-17



APPROVED FOR
CONSTRUCTION

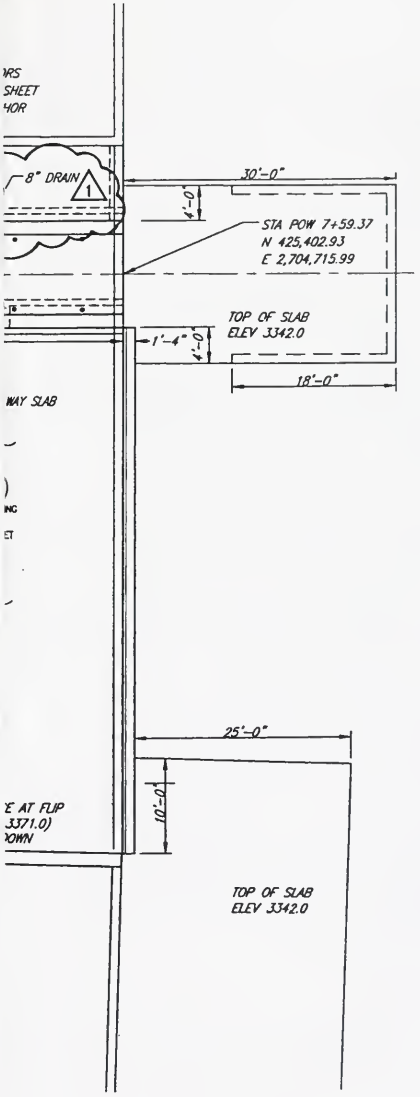
DWG TR515027

NO.	BY	DATE	REVISION DESCRIPTION
1			CHANGE LOCATION OF 8" DRAIN, ADDENDUM #1, ITEM 32

UTLET WORKS DOWNSTREAM AREA
PLAN

J17

SHEET
S-69



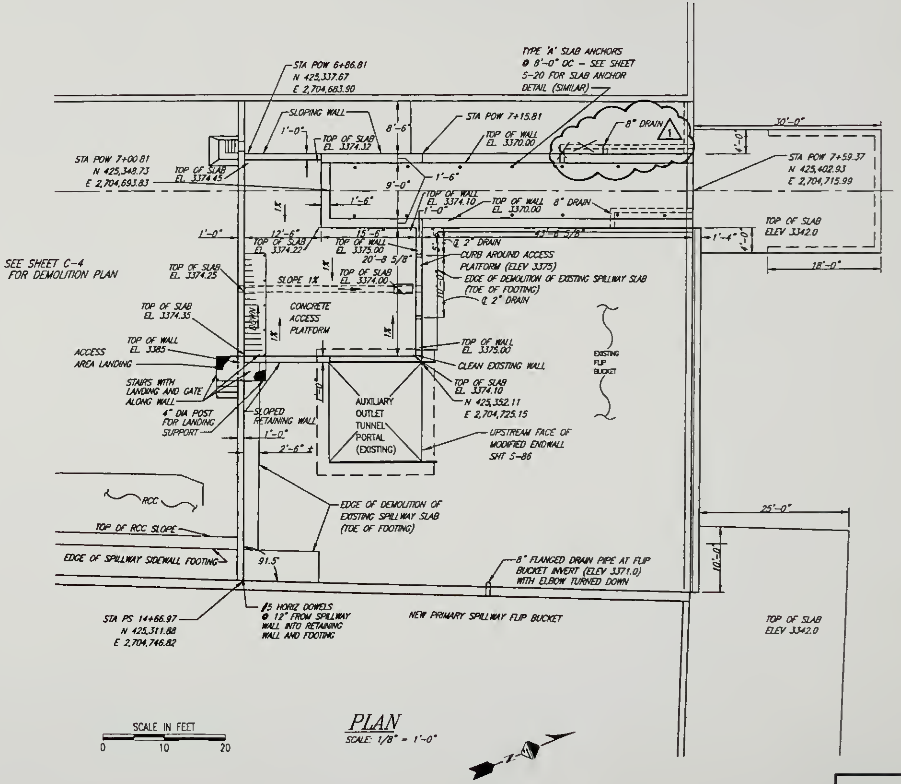
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
1			CHANGE LOCATION OF 8" DRAIN, ADDENDUM #1, ITEM 32

OUTLET WORKS DOWNSTREAM AREA
PLAN

J17

SHEET
S-69



PLAN
SCALE: 1/8" = 1'-0"

APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
1			CHANGE LOCATION OF 8" DRAIN, ADDENDUM #1, ITEM 32

DG — DRAWN
CRS — DESIGNED
– — CHECKED
– — APPROVED
7/97 — DATE
141.9601 — PROJECT NO

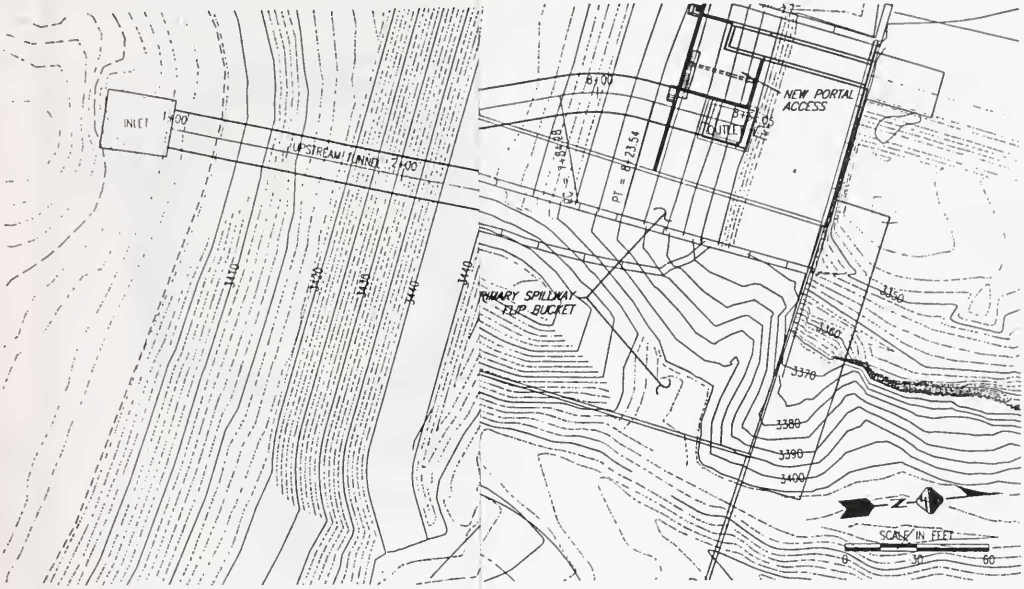
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

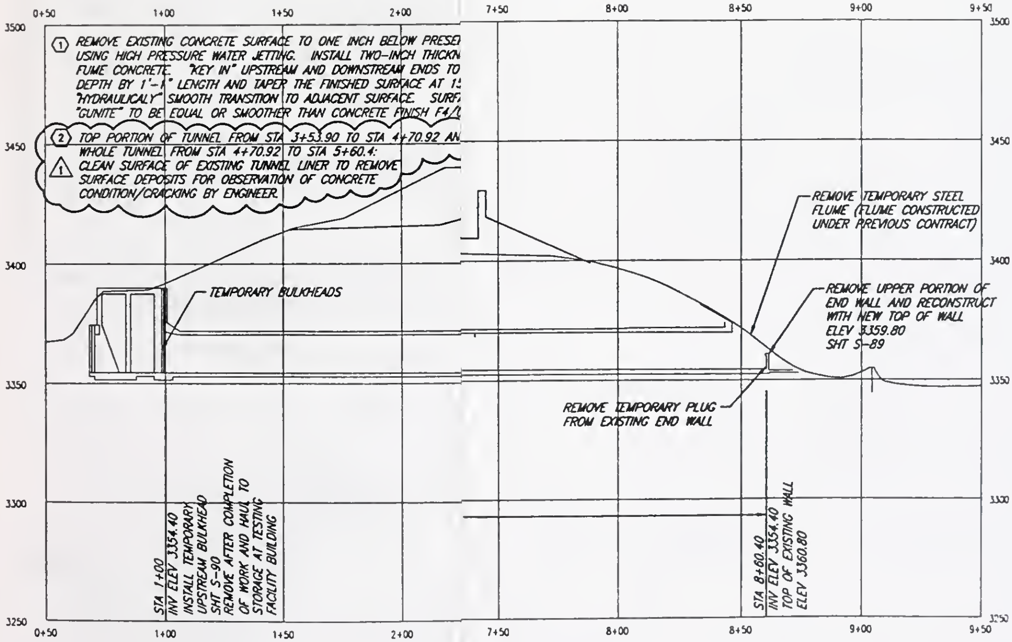
Prepared By:
ESA CONSULTANTS INC.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

OUTLET WORKS DOWNSTREAM AREA
PLAN

J17

SHEET
S-69




0+50
1+00
1+50
2+00
7+50
8+00
8+50
9+00
9+50
3500
3450
3400
3350
3300
3250
TEMPORARY BULKHEADS
REMOVE TEMPORARY STEEL FLUME (FLUME CONSTRUCTED UNDER PREVIOUS CONTRACT)
REMOVE UPPER PORTION OF END WALL AND RECONSTRUCT WITH NEW TOP OF WALL ELEV 3359.80 SHT S-89
REMOVE TEMPORARY PLUG FROM EXISTING END WALL
STA 1+00 INV ELEV 3354.40 INSTALL TEMPORARY UPSTREAM BULKHEAD SHT S-90 REMOVE AFTER COMPLETION OF WORK AND HAUL TO STORAGE AT TESTING FACILITY BUILDING
STA 8+60.40 INV ELEV 3354.40 TOP OF EXISTING WALL ELEV 3360.80

① REMOVE EXISTING CONCRETE SURFACE TO ONE INCH BELOW PRESE
USING HIGH PRESSURE WATER JETTING. INSTALL TWO-INCH THICKN
FUME CONCRETE. "KEY IN" UPSTREAM AND DOWNSTREAM ENDS TO
DEPTH BY 1'-1" LENGTH AND TAPER THE FINISHED SURFACE AT 1
"HYDRAULICALY" SMOOTH TRANSITION TO ADJACENT SURFACE. SURF
"GUNITE" TO BE EQUAL OR SMOOTHER THAN CONCRETE FINISH F4/

② TOP PORTION OF TUNNEL FROM STA 3+53.90 TO STA 4+70.92 AN
WHOLE TUNNEL FROM STA 4+70.92 TO STA 5+60.4:
CLEAN SURFACE OF EXISTING TUNNEL LINER TO REMOVE
SURFACE DEPOSITS FOR OBSERVATION OF CONCRETE
CONDITION/CRACKING BY ENGINEER.

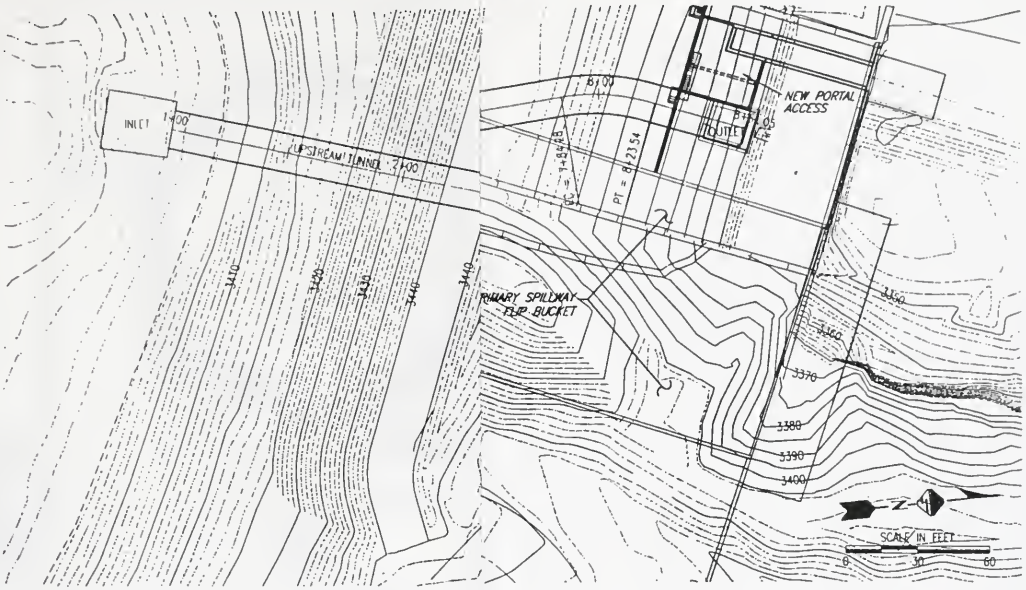
APPROVED FOR CONSTRUCTION

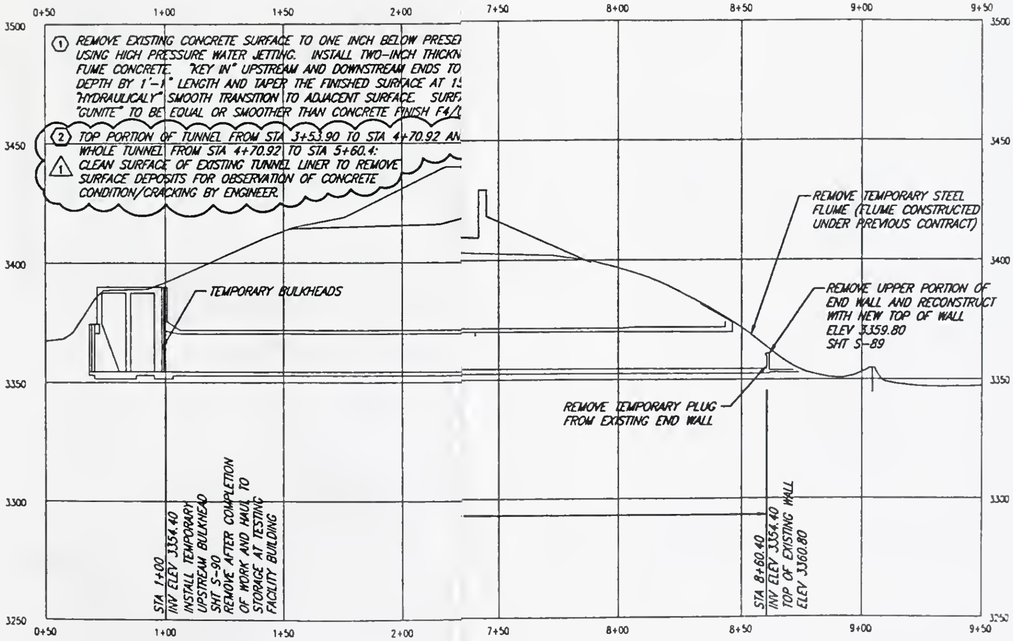
NO	BY	DATE	REVISION DESCRIPTION
1			ADDED NOTE, ADDENDUM #1 ITEM 26

AUXILIARY OUTLET WORKS
PLAN AND PROFILE

J19

SHEET C-18





① REMOVE EXISTING CONCRETE SURFACE TO ONE INCH BELOW PRESE
USING HIGH PRESSURE WATER JETTING. INSTALL TWO-INCH THICKN
FUME CONCRETE. "KEY IN" UPSTREAM AND DOWNSTREAM ENDS TO
DEPTH BY 1'-1" LENGTH AND TAPER THE FINISHED SURFACE AT 1
"HYDRAULICALY" SMOOTH TRANSITION TO ADJACENT SURFACE. SURF
"GUNITE" TO BE EQUAL OR SMOOTHER THAN CONCRETE FINISH F4/

② TOP PORTION OF TUNNEL FROM STA 3+53.90 TO STA 4+70.92 AN
WHOLE TUNNEL FROM STA 4+70.92 TO STA 5+60.4:
△1 CLEAN SURFACE OF EXISTING TUNNEL LINER TO REMOVE SURFACE DEPOSITS FOR OBSERVATION OF CONCRETE CONDITION/CRACKING BY ENGINEER.

TEMPORARY BULKHEADS

REMOVE TEMPORARY STEEL FLUME (FLUME CONSTRUCTED UNDER PREVIOUS CONTRACT)

REMOVE UPPER PORTION OF END WALL AND RECONSTRUCT WITH NEW TOP OF WALL ELEV 3359.80 SHT S-89

REMOVE TEMPORARY PLUG FROM EXISTING END WALL

STA 1+00
INV ELEV 3354.40
INSTALL TEMPORARY UPSTREAM BULKHEAD SHT S-90
REMOVE AFTER COMPLETION OF WORK AND HAUL TO STORAGE AT TESTING FACILITY BUILDING

STA 8+60.40
INV ELEV 3354.40
TOP OF EXISTING WALL ELEV 3360.80

APPROVED FOR CONSTRUCTION

NO.	BY	DATE	REVISION DESCRIPTION
1			ADDED NOTE, ADDENDUM 1 ITEM 26

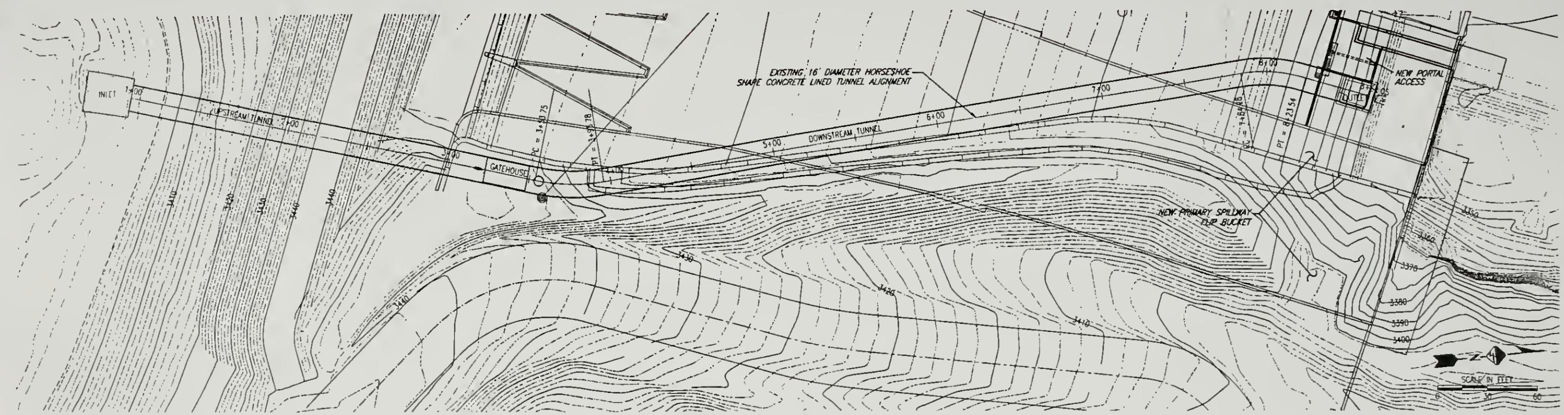
AUXILIARY OUTLET WORKS
PLAN AND PROFILE

J19

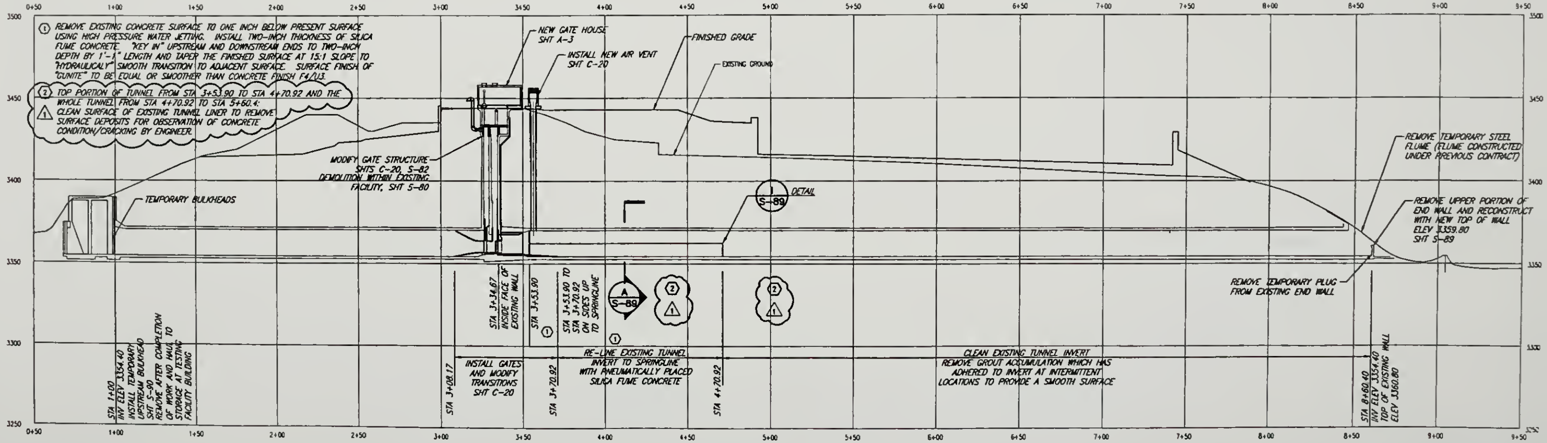
SHEET
C-18

REF 9PC020 TR51F004 009 102 187 186 189 190

DWG TR51F018



PLAN VIEW


① REMOVE EXISTING CONCRETE SURFACE TO ONE INCH BELOW PRESENT SURFACE USING HIGH PRESSURE WATER JETTING. INSTALL TWO-INCH THICKNESS OF SILICA FUME CONCRETE. "KEY IN" UPSTREAM AND DOWNSTREAM ENDS TO TWO-INCH DEPTH BY 1'-1" LENGTH AND TAPER THE FINISHED SURFACE AT 15:1 SLOPE TO "HYDRAULICALY" SMOOTH TRANSITION TO ADJACENT SURFACE. SURFACE FINISH OF "GUNITE" TO BE EQUAL OR SMOOTHER THAN CONCRETE FINISH F4/U3.
② TOP PORTION OF TUNNEL FROM STA 3+53.90 TO STA 4+70.92 AND THE WHOLE TUNNEL FROM STA 4+70.92 TO STA 5+60.4:
1 CLEAN SURFACE OF EXISTING TUNNEL LINER TO REMOVE SURFACE DEPOSITS FOR OBSERVATION OF CONCRETE CONDITION/CRACKING BY ENGINEER.
NEW GATE HOUSE SHT A-3
INSTALL NEW AIR VENT SHT C-20
FINISHED GRADE
EXISTING GROUND
MODIFY GATE STRUCTURE SHTS C-20, S-82 DEMOLITION WITHIN EXISTING FACILITY, SHT S-80
TEMPORARY BULKHEADS
DETAIL 1 S-89
REMOVE TEMPORARY STEEL FLUME (FLUME CONSTRUCTED UNDER PREVIOUS CONTRACT)
REMOVE UPPER PORTION OF END WALL AND RECONSTRUCT WITH NEW TOP OF WALL ELEV 3359.80 SHT S-89
REMOVE TEMPORARY PLUG FROM EXISTING END WALL
A S-89
STA 1+00 INV ELEV 3354.40 INSTALL TEMPORARY UPSTREAM BULKHEAD SHT S-90 REMOVE AFTER COMPLETION OF WORK AND HAUL TO STORAGE AT TESTING FACILITY BUILDING
STA 3+08.17
INSTALL GATES AND MODIFY TRANSITIONS SHT C-20
STA 3+34.67 INSIDE FACE OF EXISTING WALL
STA 3+53.90
STA 3+70.92
STA 3+53.90 TO STA 3+70.92 ON SIDES UP TO SPRINGLINE
RE-LINE EXISTING TUNNEL INVERT TO SPRINGLINE WITH PNEUMATICALLY PLACED SILICA FUME CONCRETE
STA 4+70.92
CLEAN EXISTING TUNNEL INVERT REMOVE GROUT ACCUMULATION WHICH HAS ADHERED TO INVERT AT INTERMITTENT LOCATIONS TO PROVIDE A SMOOTH SURFACE
STA 8+60.40 INV ELEV 3354.40 TOP OF EXISTING WALL ELEV 3360.80
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
5+50
6+00
6+50
7+00
7+50
8+00
8+50
9+00
9+50
3500
3450
3400
3350
3300
3250

PROFILE

SCALE: 1" = 30'

APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION
1			ADDED NOTE, ADDENDUM #1 ITEM 26

MAK DRAWN — SM DESIGNED — WRK CHECKED
WRK APPROVED — 7/97 DATE — 141.8501 PROJECT NO

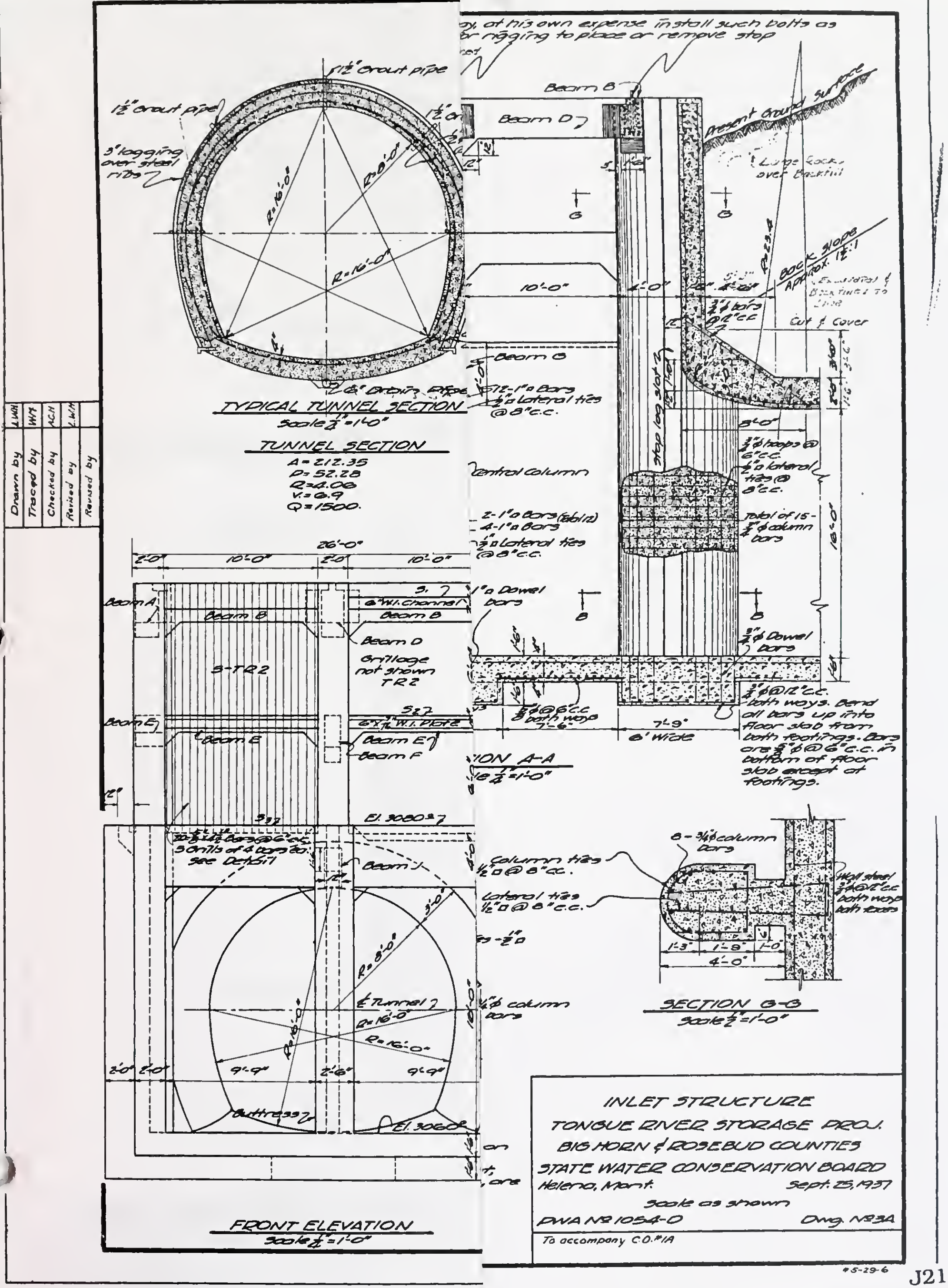
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
815 West Mendenhall, Suite C-1, Bozeman MT. 59715

AUXILIARY OUTLET WORKS
PLAN AND PROFILE

J19

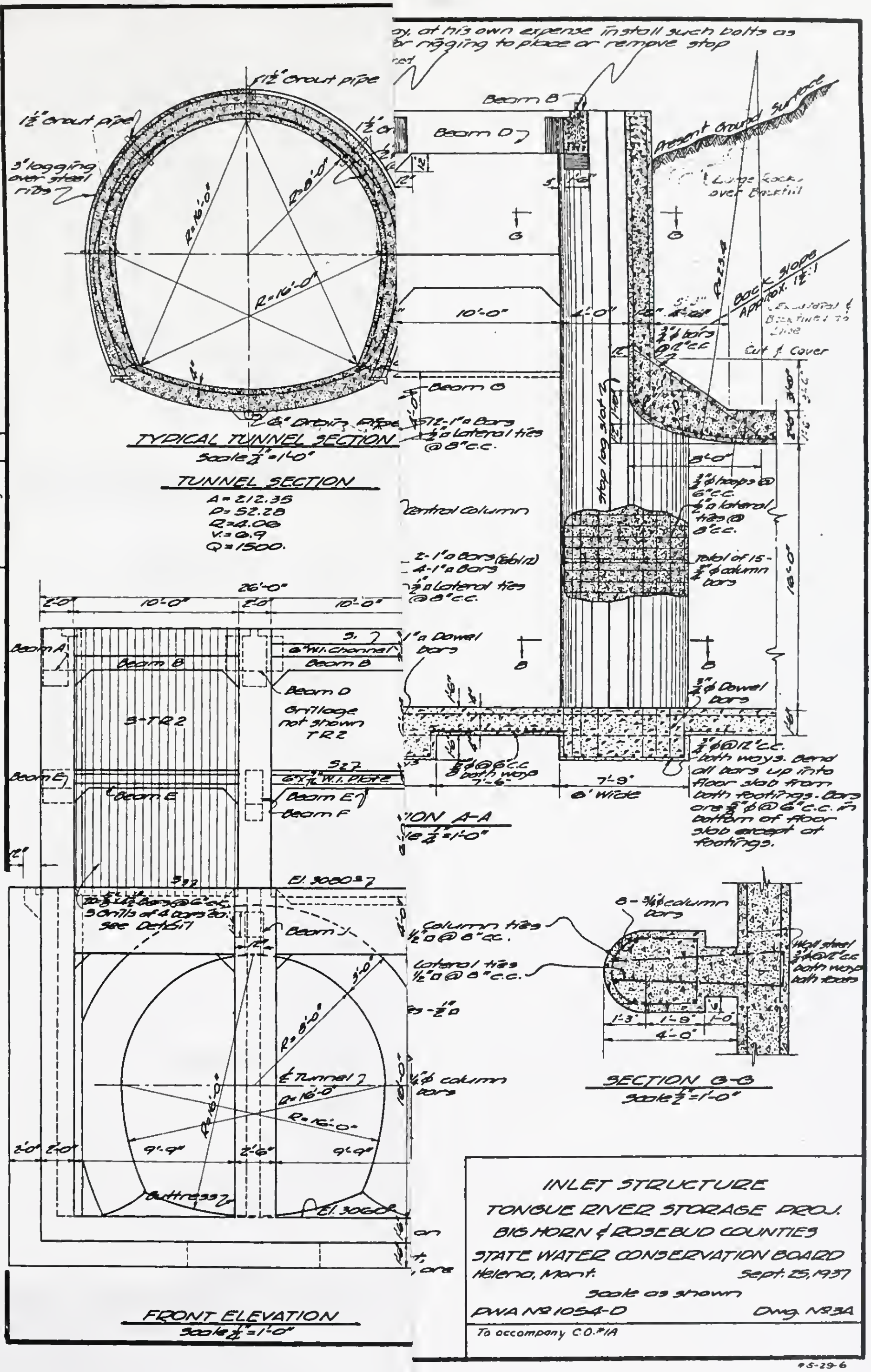
SHEET C-18



INLET STRUCTURE
TONGUE RIVER STORAGE PROJ.
BIG HORN & ROSEBUD COUNTIES
STATE WATER CONSERVATION BOARD
Helena, Mont. Sept. 25, 1937
Scale as shown
PWA № 1054-D Dwg. № 3A

To accompany C.O. #1A

#5-29-6

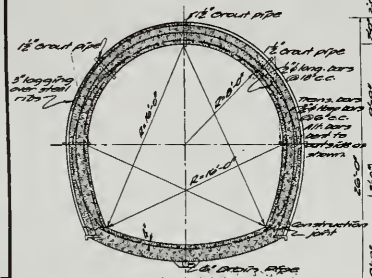


INLET STRUCTURE
TONGUE RIVER STORAGE PROJ.
BIG HORN & ROSEBUD COUNTIES
STATE WATER CONSERVATION BOARD
Helena, Mont. Sept. 25, 1937
Scale as shown
PWA No. 1054-D Dwg. No. 3A
To accompany C.O. #1A

4-5-29-6

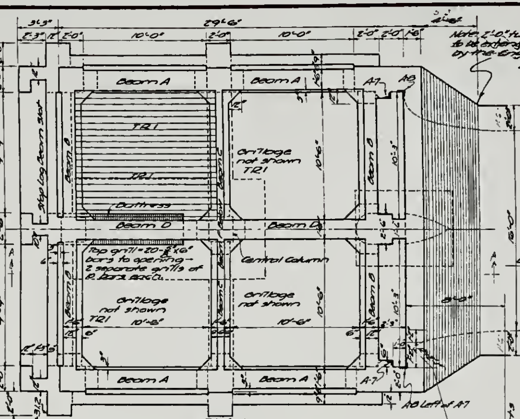
J21

Drawn by	LWH
Traced by	WH
Checked by	ACH
Revised by	LWH
Revised by	

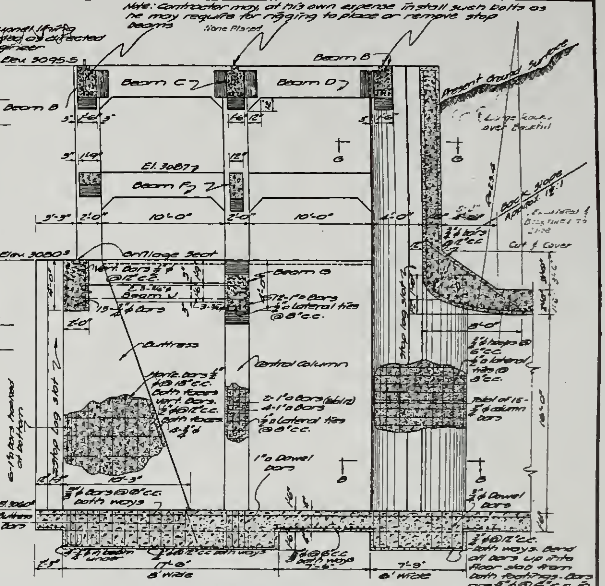


TYPICAL TUNNEL SECTION
Scale ⅛"=1'-0"

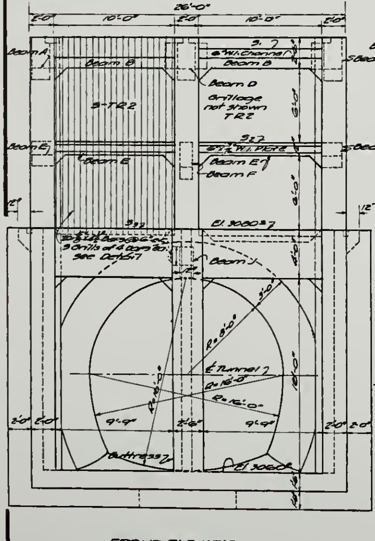
TUNNEL SECTION
A=212.35
P=52.28
R=4.06
V=6.9
Q=1500.



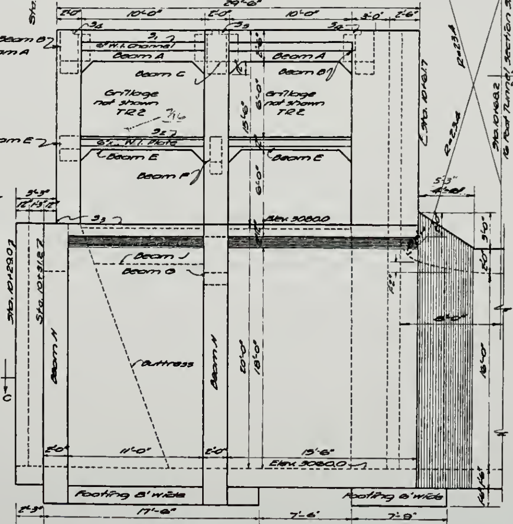
PLAN
Scale ⅛"=1'-0"


Note: Contractor may, at his own expense install such bolts as he may require for rigging to place or remove stop beams
None Placed
Elev. 3095.5
Beam B
Beam C
Beam D
Beam B
Present Ground Surface
Large Rock over Backfill
El. 3087
Beam F
5'-3"
2'-0"
10'-0"
2'-0"
10'-0"
2'-0"
Back Slope Approx. 1½:1
Cut & Cover
Elev. 3080.3
Grillage Seat
Vert. bars ⅞" ϕ @12" c.c.
Beam J
Beam G
12-1" ϕ Bars ½" ϕ Lateral ties @8" c.c.
13-⅞" ϕ Bars
Buttress
Central Column
Stop log slot
⅞" ϕ hoops @6" c.c. ½" ϕ lateral ties @8" c.c.
Total of 15-⅞" ϕ column bars
Horiz. bars ½" ϕ @18" c.c. both faces. Vert. bars ⅞" ϕ @8" c.c. both faces
2-1" ϕ Bars (Table)
4-1" ϕ Bars
½" ϕ Lateral ties @8" c.c.
1" ϕ Dowel bars
⅞" ϕ Dowel bars
⅝" ϕ Bars @8" c.c. both ways
El. 3060.6
Buttress Bars
12'-6"
8' wide
7'-9"
8' wide
¾" ϕ @12" c.c. both ways. Bend all bars up into floor slab from both footings. Bars are ⅝" ϕ @6" c.c. in bottom of floor slab except at footings.
B
B
C
C

SECTION A-A
Scale ⅛"=1'-0"

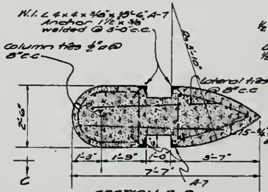


FRONT ELEVATION
Scale ⅛"=1'-0"

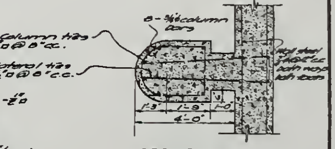


SIDE ELEVATION
Scale ⅛"=1'-0"

Structure to be carried to firm foundation as directed by the Engineer. Footings may be omitted if floor is on solid rock.


W.I. ∠ 4x4x⅜"x35'-6" A-7
Anchor 1½"x⅜" welded @3'-0" c.c.
Column ties ½" ϕ @8" c.c.
Lateral ties ½" ϕ @8" c.c.
15-⅞" ϕ column bars
2'-6"
1'-3"
1'-9"
1'-0"
3'-7"
7'-7"
A-7

SECTION B-B
Scale ½"=1'-0"

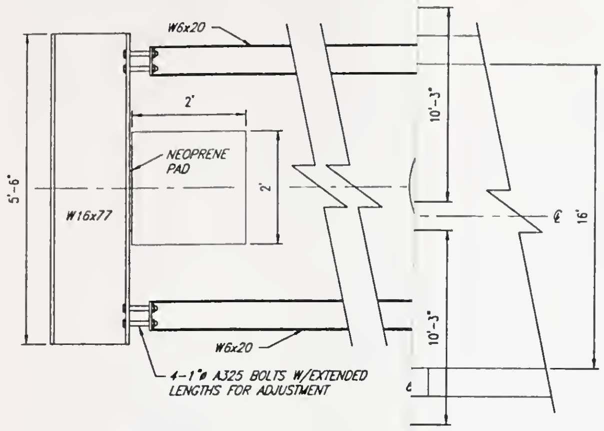


SECTION C-C
Scale ½"=1'-0"

Note:
Details of grillages are shown on sheet No. 3C.
Details of beam reinforcement, other than shown on this drawing, are shown on sheet No. 3B.
See Dwg. #3B for Sec. C.C.

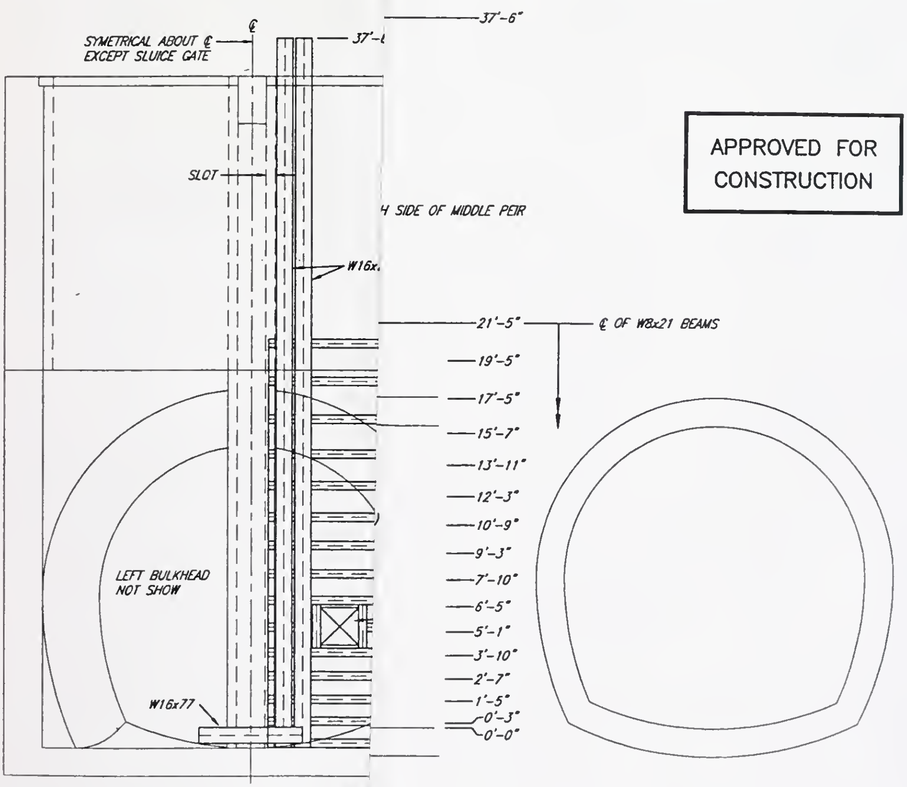
INLET STRUCTURE
TONGUE RIVER STORAGE PROJ.
BIG HORN & ROSEBUD COUNTIES
STATE WATER CONSERVATION BOARD
Helena, Mont. Sept. 25, 1937
Scale as shown
PWA No. 1054-D Dwg. No. 3A

To accompany C.O. #1A



PLAN SECTION OF MIDDLE PIER

SCALE: 3/4"=1'-0"



APPROVED FOR
CONSTRUCTION

SCALE: 1/4"=1'-0"

SECTION OF INLET
LOOKING DOWNSTREAM AT TUNNEL "

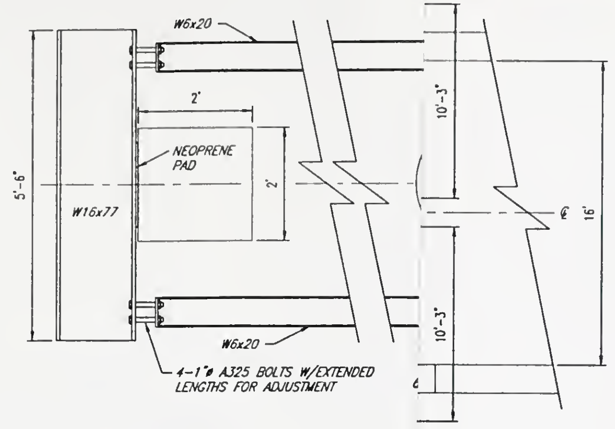
SCALE: 1/4"=1'-0"

NO	BY	DATE	REVISION DESCRIPTION

IARY OUTLET WORKS INTAKE STRUCTURE
INLET BULKHEAD

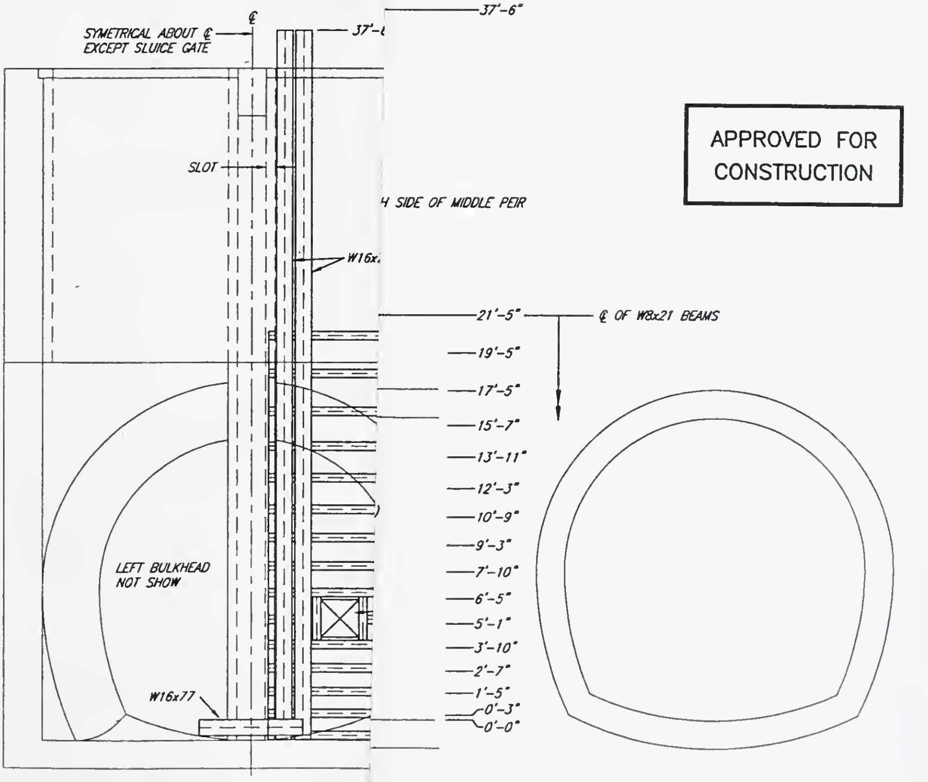
J23

SHEET
S-90



PLAN SECTION OF MIDDLE PIER

SCALE: 3/4"=1'-0"



APPROVED FOR CONSTRUCTION

SECTION OF INLET
LOOKING DOWNSTREAM AT TUNNEL

SCALE: 1/4"=1'-0"

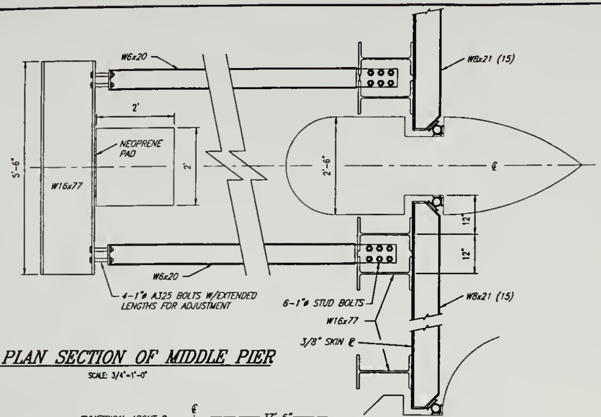
SCALE: 1/4"=1'-0"

NO	BY	DATE	REVISION DESCRIPTION

IARY OUTLET WORKS INTAKE STRUCTURE
INLET BULKHEAD

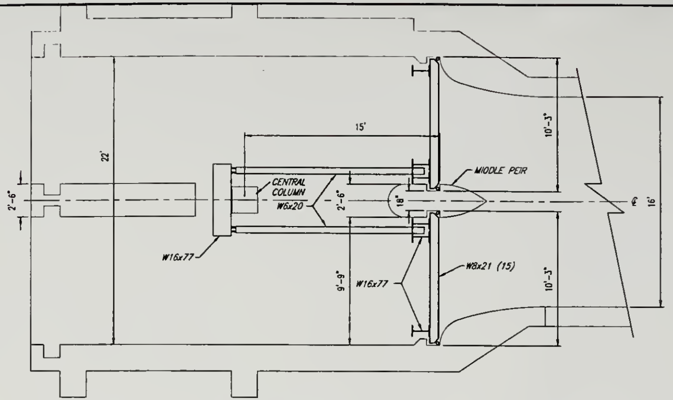
J23

SHEET
S-90



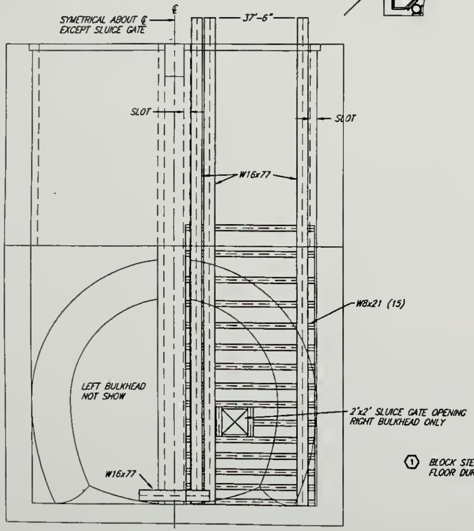
PLAN SECTION OF MIDDLE PIER

SCALE: 3/4"=1'-0"



FLOOR PLAN OF AUXILIARY TUNNEL INLET

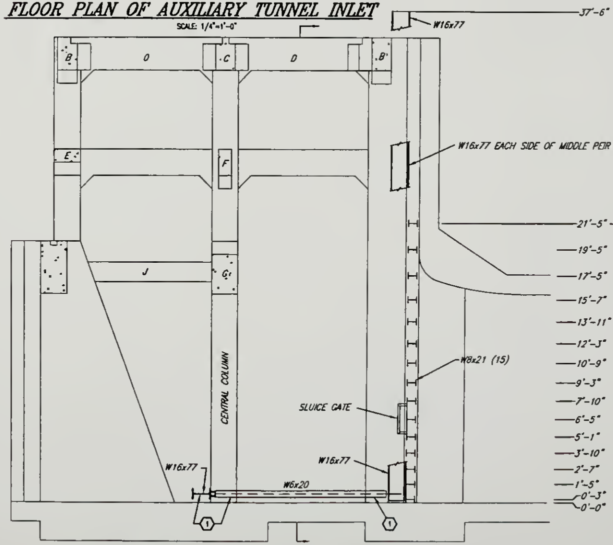
SCALE: 1/4"=1'-0"


SYMETRICAL ABOUT ¢ EXCEPT SLUICE GATE
¢
37'-6"
SLOT
SLOT
W16x77
W8x21 (15)
LEFT BULKHEAD NOT SHOW
2'x2' SLUICE GATE OPENING RIGHT BULKHEAD ONLY
W16x77

SECTION OF INLET
LOOKING DOWNSTREAM AT TUNNEL "PORTAL"/HEADWAY

SCALE: 1/4"=1'-0"

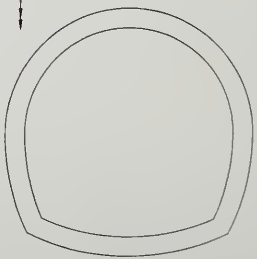
① BLOCK STEEL MEMBERS FROM FLOOR DURING ERECTION.



SECTION AT "RIGHT" BULKHEAK

SCALE: 1/4"=1'-0"

APPROVED FOR CONSTRUCTION



SCALE: 1/4"=1'-0"

NO	BY	DATE	REVISION DESCRIPTION

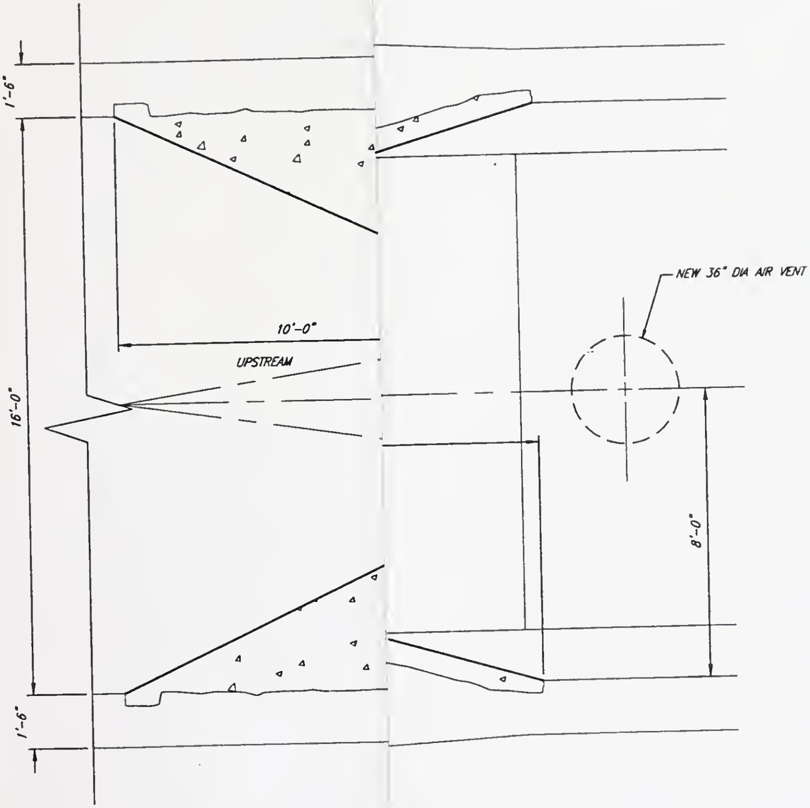
KRW DRAWN	PAS DESIGNED	CHECKED
WRK APPROVED	7/97 DATE	141.9501 PROJECT NO.

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

AUXILIARY OUTLET WORKS INTAKE STRUCTURE
INLET BULKHEAD
J23

SHEET
S-90



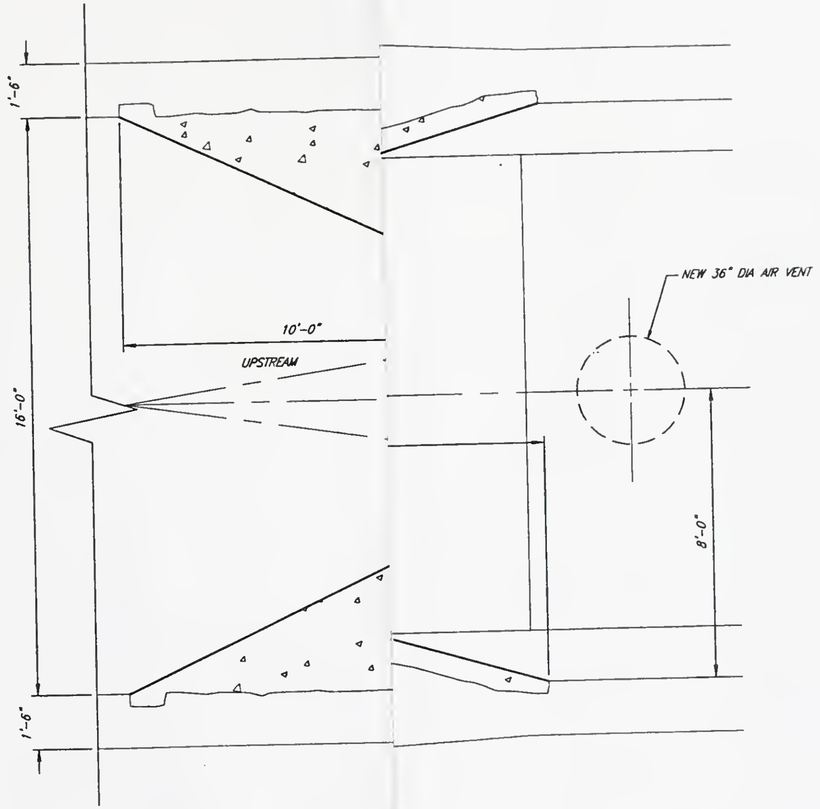
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

LIARY OUTLET WORKS GATE STRUCTURE
PLAN

J25

SHEET
C-19



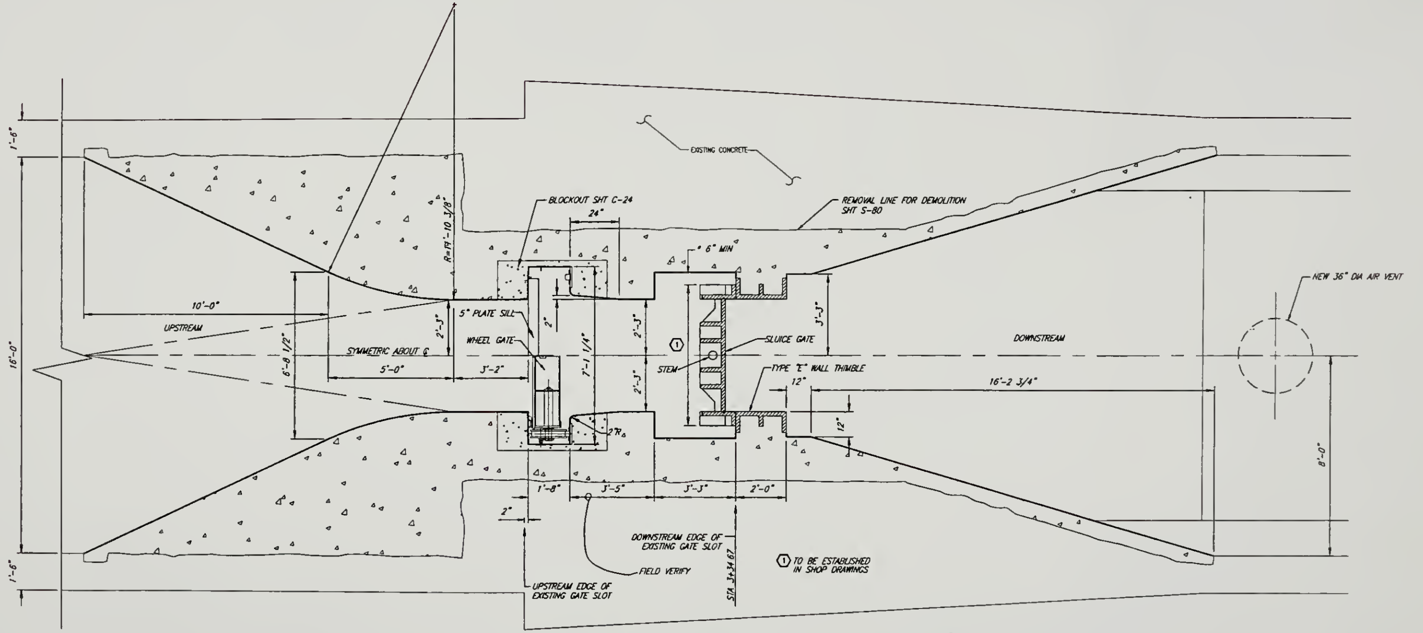
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

LIARY OUTLET WORKS GATE STRUCTURE
PLAN

J25

SHEET
C-19



GATE CHAMBER SECTIONAL PLAN

SCALE: 1/2" = 1'-0"

N

APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

MAK
DRAWN

WRK
DESIGNED

CHECKED

WRK
APPROVED

7/97
DATE

141.9501
PROJECT NO

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

AUXILIARY OUTLET WORKS GATE STRUCTURE
PLAN

J25

SHEET
C-19

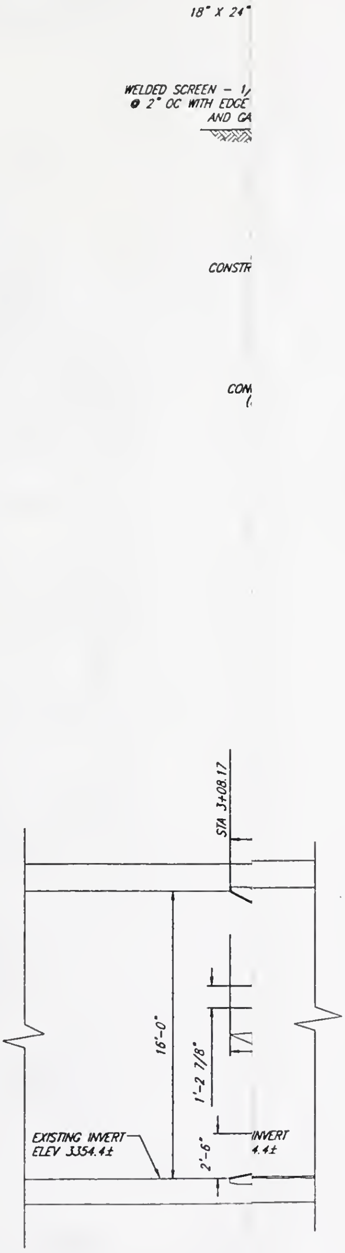
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

ARY OUTLET WORKS GATE STRUCTURE
SECTION

J27

SHEET
C-20



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CONSTRUCTION

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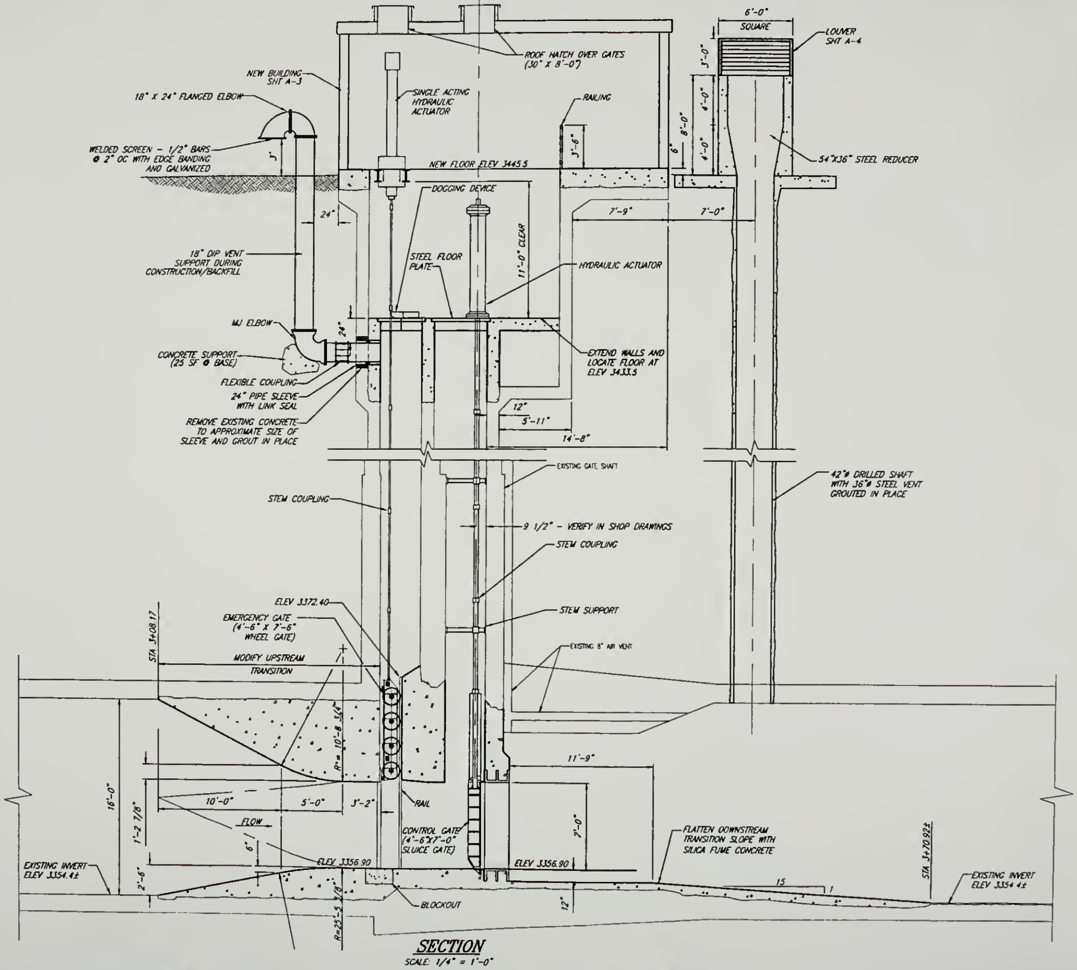
ARY OUTLET WORKS GATE STRUCTURE
SECTION

J27

SHEET
C-20


ROOF HATCH OVER GATES (30" X 8'-0")
6'-0" SQUARE
LOUVER SHT A-4
NEW BUILDING SHT A-3
18" X 24" FLANGED ELBOW
SINGLE ACTING HYDRAULIC ACTUATOR
RAILING
WELDED SCREEN - 1/2" BARS @ 2" OC WITH EDGE BANDING AND GALVANIZED
NEW FLOOR ELEV 3445.5
54"X36" STEEL REDUCER
3'-0"
4'-0"
8'-0"
4'-0"
6"
3'-6"
3'
DOGGING DEVICE
24"
7'-9"
7'-0"
18" DIP VENT SUPPORT DURING CONSTRUCTION/BACKFILL
STEEL FLOOR PLATE
11'-0" CLEAR
HYDRAULIC ACTUATOR
MJ ELBOW
24"
CONCRETE SUPPORT (25 SF @ BASE)
EXTEND WALLS AND LOCATE FLOOR AT ELEV 3433.5
FLEXIBLE COUPLING
24" PIPE SLEEVE WITH LINK SEAL
REMOVE EXISTING CONCRETE TO APPROXIMATE SIZE OF SLEEVE AND GROUT IN PLACE
12"
5'-11"
14'-8"
EXISTING GATE SHAFT
42"ø DRILLED SHAFT WITH 36"ø STEEL VENT GROUTED IN PLACE
STEM COUPLING
9 1/2" - VERIFY IN SHOP DRAWINGS
STEM COUPLING
STEM SUPPORT
ELEV 3372.40
EMERGENCY GATE (4'-6" X 7'-6" WHEEL GATE)
EXISTING 8" AIR VENT
STA 3+08.17
MODIFY UPSTREAM TRANSITION
R= 10'-8 3/4"
11'-9"
16'-0"
10'-0"
5'-0"
3'-2"
RAIL
FLOW
1'-2 7/8"
6"
CONTROL GATE (4'-6"X7'-0" SLUICE GATE)
7'-0"
FLATTEN DOWNSTREAM TRANSITION SLOPE WITH SILICA FUME CONCRETE
STA 3+70.92±
EXISTING INVERT ELEV 3354.4±
ELEV 3356.90
ELEV 3356.90
2'-6"
15
1
EXISTING INVERT ELEV 3354.4±
BLOCKOUT
12"
R=25'-5 7/8"

SECTION

SCALE: 1/4" = 1'-0"

APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

MAK DRAWN
WRK DESIGNED
WRK CHECKED
WRK APPROVED
7/97 DATE
141.9501 PROJECT NO

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

AUXILIARY OUTLET WORKS GATE STRUCTURE
SECTION

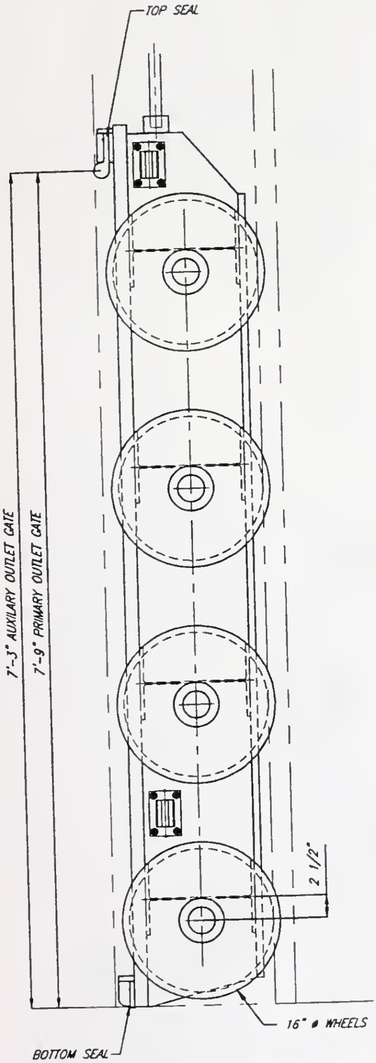
J27

SHEET
C-20

Connections have been modified

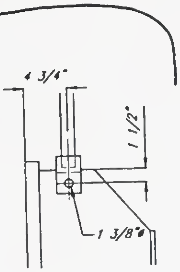
SCALE IN FEET
0 8" 16"
SCALE: 1 1/2"=1'-0"

3"ø "LUBRITE" BE



END VIEW

–A



SECTION B–B

APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

EMERGENCY (FIXED WHEEL) GATE
ASSEMBLY DRAWING
J29

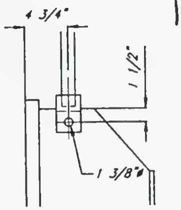
SHEET
C-21

Connections have been modified

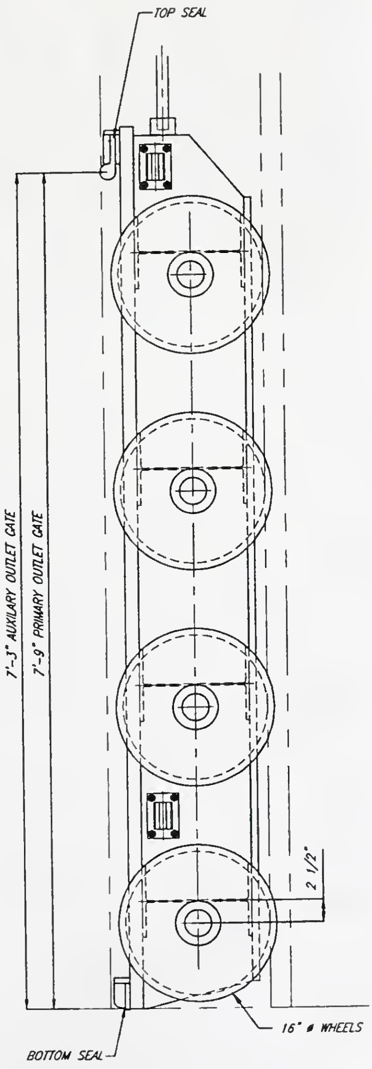
SCALE IN FEET
0 8' 16'
SCALE: 1 1/2"=1'-0"

3"ø "LUBRITE" BE

-A



SECTION B-B



END VIEW

APPROVED FOR
CONSTRUCTION

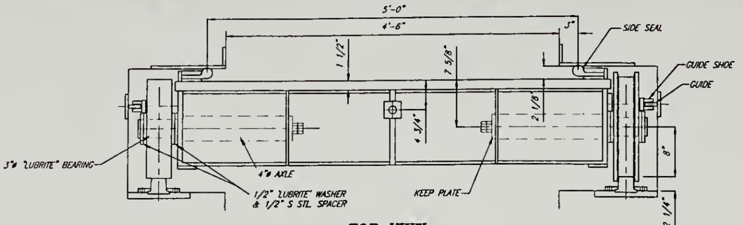
DWG. TR51F924

NO	BY	DATE	REVISION DESCRIPTION

EMERGENCY (FIXED WHEEL) GATE
ASSEMBLY DRAWING
J29

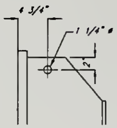
SHEET
C-21

SCALE IN FEET
0 8" 16"
SCALE: 1 1/2"=1'-0"

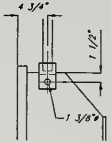


TOP VIEW

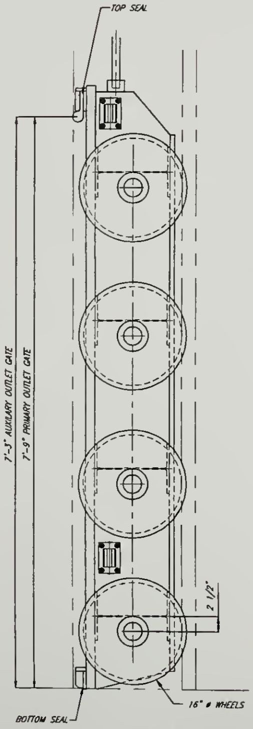
Connections have been modified



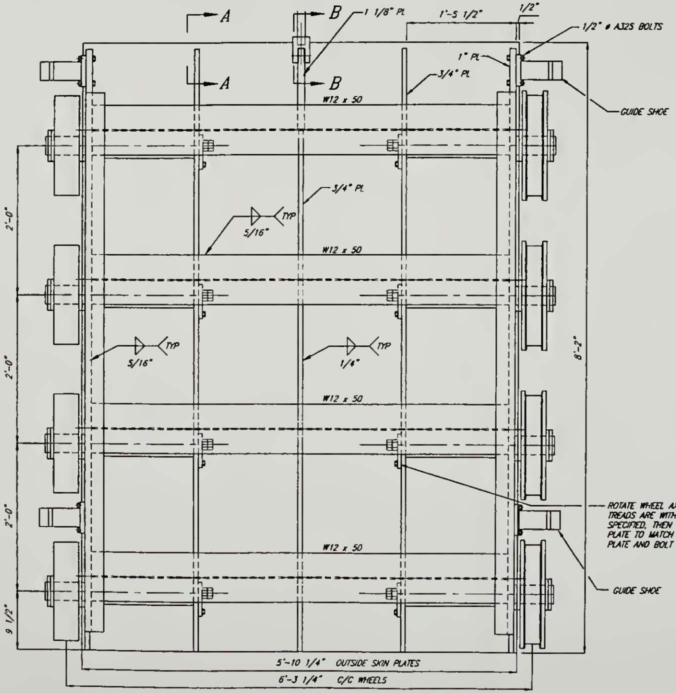
SECTION A-A



SECTION B-B



END VIEW



ROTATE WHEEL AXLES UNTIL WHEEL TREADS ARE WITHIN TOLERANCES SPECIFIED, THEN DRILL 1/2" STIFFENER PLATE TO MATCH HOLE IN KEEP PLATE AND BOLT IN PLACE.

ELEVATION

APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

D.H DRAWN
D.H DESIGNED
CHECKED
APPROVED
7/97 DATE
141 9501 PROJECT NO

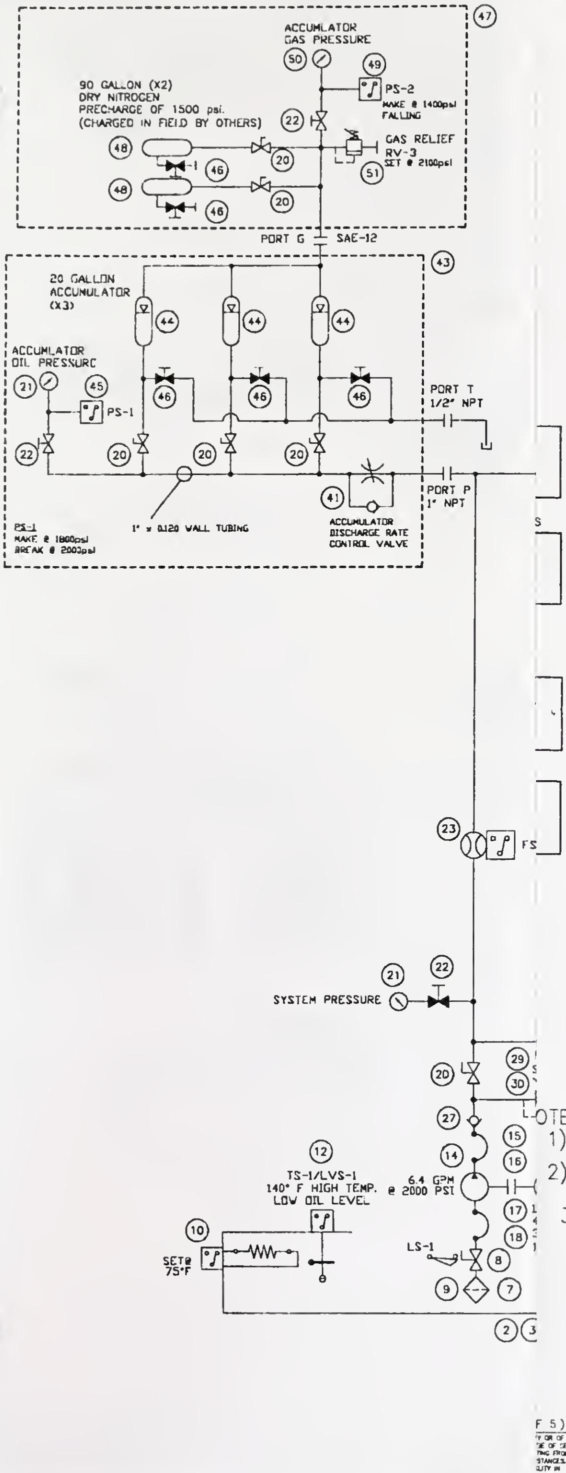
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

EMERGENCY (FIXED WHEEL) GATE
ASSEMBLY DRAWING

J29

SHEET
C-21



UNIT SPECS AND SPECIAL INSTRUCTIONS

TEST PROCEDURE:	STANDARD
WITNESS TEST:	YES
DUPLICATE UNIT:	NO
TYPE OF PLUMBING & FITTINGS:	CARBON STEEL TUBING AND PARKER SEAL-LOK FITTINGS
SIZE RESTRICTIONS:	NONE
OIL TYPE:	PETROLEUM BASED ISO 32
COOLING REQUIREMENT:	NONE
PHENOLIC/CUSTOMER LABELS:	SORENSEN STANDARD HPU LABELS
PAINT COLOR:	SORENSEN BLUE
SPECIAL INSTRUCTIONS:	ALL WIRING FROM HYDRAULIC UNIT TO ELECTRICAL BOX IS TO BE IN SEAL-TITE CONDUIT.

NOTE: ALL SYSTEM SET POINTS AND PERFORMANCE VALUES ARE ± 5% UNLESS OTHERWISE SPECIFIED ON THE SCHEMATIC.

REVISIONS

△	DATE	CHG. BY	REVISION
△1	11/11/98	CK	AS-BUILT REVISIONS
△2	4/18/01	CK	FIELD MODIFICATIONS PER ARMA

ITEM	QTY	DESCRIPTION	PRODUCT NO.	MANUFACTURER
1	1	HPU Valve Enclosure (NEMA 12)	58-304210LP	McKinstry
2	1	Drip pan/base	DP-84"X66"X2"X3/16"	Sorensen
3	1	150 Gallon JIC Style Reservoir	100150	Vescor
4	1	Filler / Breather	w/Reservoir	Vescor
5	2	End Cover	w/Reservoir	Vescor
6	1	Site Gage	G610-18-A-1	Lube Devices, Inc.
7	2	Suction Strainer	10-1-100	Flo-Ezy
8	2	Low Pressure Suction Ball Valve	VP502P-16	Parker
9	2	Suction Ball Valve Limit Switch	BZE6-2RQ	Microswitch
10	1	Reservoir Heater (2000 Watt)	BGS717J7S4	Watlow
11	1	Reservoir Drain Ball Valve	V500P-12	Parker
12	1	Temperature / Level Switch	TL008-140F	APCO
13	2	Motor 10HP, 480VAC,3PH, 60HZ	CM3774T-M9A	Baldor
14	2	Gear Pump 6.4GPM @ 2000PSI	PZG2AR140S1	Parker
15	2	Horiz. Motor Mount	M182472A	Magnaloy
16	2	Coupling Half	200-5/8-X-5/32	Magnaloy
17	2	Coupling Half	200-1-3/8-X-5/16	Magnaloy
18	2	Coupling Insert	270	Magnaloy
19	8	Vibration Isolation Pads	RD-2GRAY	Korfund
20	7	High Pressure Isolation Ball Valve	BVHP12SSS1NA	Parker
21	2	Pressure Gage (0-3000 PSI)	CF1P-210A	PDI
22	3	Metering Valve	MV400S	Parker
23	1	Flow Meter / Switch	682-510	Hedland
24	1	Return Filter	50AT10CN25DDL1	Parker
25	1	Return Filter Gauge	923472	Parker
26	1	Return Filter Switch	926923	Parker
27	5	Check Valve	C1220S	Parker
28	1	Check Valve	C620S	Parker
29	2	Relief Valve	RA101S30	Parker
30	2	Relief Valve Body	B10-2-8T	Parker
31	1	Subplate	AD03SPS12S	Danan Products
32	1	P.O. Check Valve	CPOM2DD	Parker
33	1	Manapak Flow Control	FM2DD	Parker
34	1	Directional Control Valve	D1VW4CNYVCP	Parker
35	3	Directional Control Valve	DS121CR1-20	Parker
36	4	Directional Control Valve Body	B12-2-12T	Parker
37	4	Directional Control Valve Coil	851019-120VAC	Parker
38	2	Flow Control	N1220S	Parker
39	6	Cord Connector	C452N30012C4L	Norstat
40	1	Hand Pump	P3A-LR	Star
41	1	Flow Control	F1620S	Parker
42	1	Velocity Fuse	RBX8-1" NPT-10 GPM	Hycon
43	1	Accumulator Stand	AS-3X20GAL-98-9695/6	Sorensen
44	3	20 Gallon ASME Piston Accumulator	A9L4620D3KTE/TD	Parker
45	1	Oil Pressure Switch	836T-T352J	Allen-Bradley
46	5	Drain Valve	MV820S	Parker
47	1	Gas Bottle Stand	GBS-2X90GAL-98-9695/6	Sorensen
48	2	90 Gallon Gas Bottle	8820790B3T1S30	Parker
49	1	Gas Pressure Switch	10E14	United Electric
50	1	Gas Pressure Gage (0-3000 PSI)	CF1P-210A	PDI
51	1	Gas Pressure Relief Valve	2CRV-00	Hydro Seal
52	3	High Pressure Isolation Ball Valve	BVHP12NSS1NA	Parker
53	1	Press Reducing Valve	PR101S30	Parker
54	1	Directional Control Valve	DS121NRM	Parker

OTE:

1) ITEMS #8 AND #20 ARE PAD LOCKABLE
2) HPU VALVE ENCLOSURE HAS A LOCKING HANDLE
3) ▶◀ = NORMALLY CLOSED VALVE

▷◁ = NORMALLY OPEN VALVE

STEEL-FAB INC., TONGUE RIVER

F 5) (JOB# 98-9695-96) (CAD# STEEL49A)

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The Hope Group
70 Bearfoot Road, P.O. Box 840
Northboro, MA 01532-0840
Tel: (508) 383-7660 Fax: (508) 383-8042

SORENSEN GOVERNOR

J31 HYDRAULIC SCHEMATIC

DRAWN BY WAVE	DATE 3/4/98	SCALE	DRAWING NO.
CHK'D	APP'D	TRACED	HS204058

204058

UNIT SPECS AND SPECIAL INSTRUCTIONS	
TEST PROCEDURE:	STANDARD
WITNESS TEST:	YES
DUPLICATE UNIT:	NO
TYPE OF PLUMBING & FITTINGS:	CARBON STEEL TUBING AND PARKER SEAL-LOK FITTINGS
SIZE RESTRICTIONS:	NONE
OIL TYPE:	PETROLEUM BASED ISO 32
COOLING REQUIREMENT:	NONE
PHENOLIC/CUSTOMER LABELS:	SORENSEN STANDARD HPU LABELS
PAINT COLOR:	SORENSEN BLUE
SPECIAL INSTRUCTIONS:	ALL WIRING FROM HYDRAULIC UNIT TO ELECTRICAL BOX IS TO BE IN SEAL-TITE CONDUIT.

NOTE: ALL SYSTEM SET POINTS AND PERFORMANCE VALUES ARE ± 5% UNLESS OTHERWISE SPECIFIED ON THE SCHEMATIC.

REVISIONS

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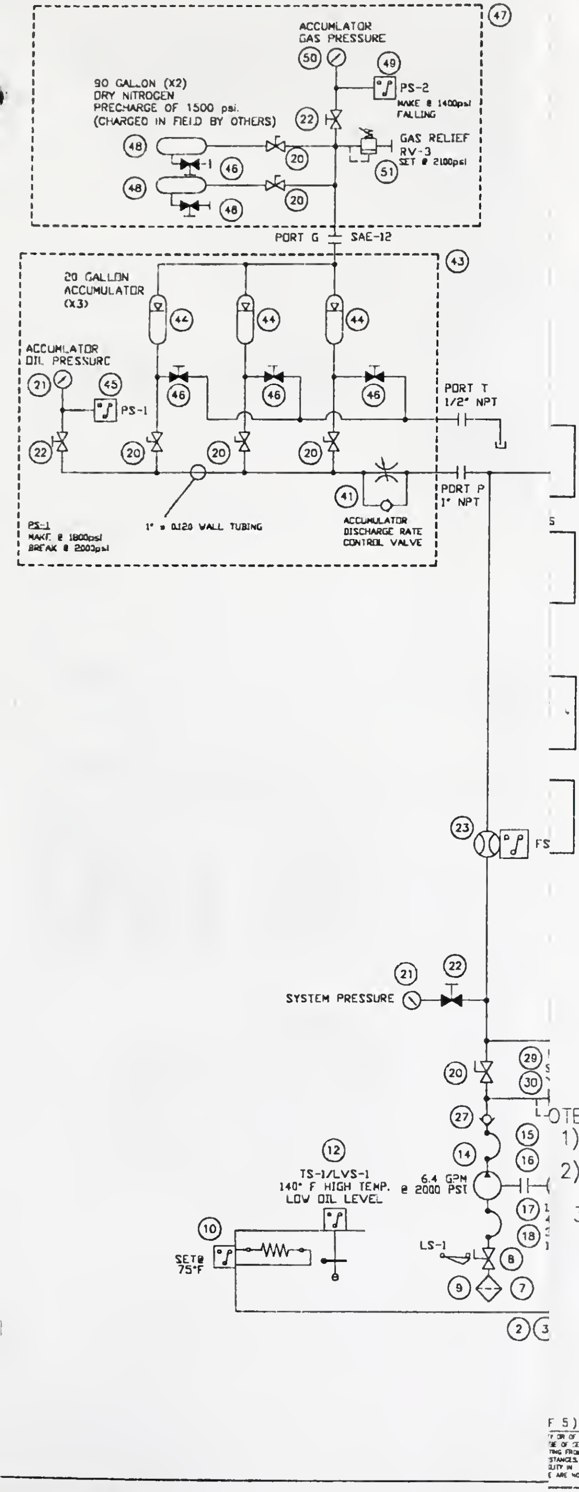
△1	11/11/98	CK	AS-BUILT REVISIONS
△2	4/18/01	CK	FIELD MODIFICATIONS PER ARMA

ITEM	QTY	DESCRIPTION	PRODUCT NO.	MANUFACTURER
1	1	HPU Valve Enclosure (NEMA 12)	58-304210LP	McKinstry
2	1	Drip pan/base	DP-84"X66"X2"X3/16"	Sorensen
3	1	150 Gallon JIC Style Reservoir	100150	Vescor
4	1	Filler / Breather	w/Reservoir	Vescor
5	2	End Cover	w/Reservoir	Vescor
6	1	Site Gage	G610-18-A-1	Lube Devices, Inc.
7	2	Suction Strainer	10-1-100	Flo-Ezy
8	2	Low Pressure Suction Ball Valve	VP502P-16	Parker
9	2	Suction Ball Valve Limit Switch	BZE6-2RQ	Microswitch
10	1	Reservoir Heater (2000 Watt)	BGS717J7S4	Watlow
11	1	Reservoir Drain Ball Valve	V500P-12	Parker
12	1	Temperature / Level Switch	TL008-140F	APCO
13	2	Motor 10HP, 480VAC,3PH, 60HZ	CM3774T-M9A	Baldor
14	2	Gear Pump 6.4GPM @ 2000PSI	PZG2AR140S1	Parker
15	2	Horiz. Motor Mount	M182472A	Magnaloy
16	2	Coupling Half	200-5/8-X-5/32	Magnaloy
17	2	Coupling Half	200-1-3/8-X-5/16	Magnaloy
18	2	Coupling Insert	270	Magnaloy
19	8	Vibration Isolation Pads	RD-2GRAY	Korfund
20	7	High Pressure Isolation Ball Valve	8VHP12SSSINA	Parker
21	2	Pressure Gage (0-3000 PSI)	CF1P-210A	PDI
22	3	Metering Valve	MV400S	Parker
23	1	Flow Meter / Switch	682-510	Hedland
24	1	Return Filter	50AT10CN25DDL1	Parker
25	1	Return Filter Gauge	923472	Parker
26	1	Return Filter Switch	926923	Parker
27	5	Check Valve	C1220S	Parker
28	1	Check Valve	C620S	Parker
29	2	Relief Valve	RA101S30	Parker
30	2	Relief Valve Body	810-2-8T	Parker
31	1	Subplate	AD03SPS12S	Daman Products
32	1	P.O. Check Valve	CPOM2DD	Parker
33	1	Monopak Flow Control	FM2DD	Parker
34	1	Directional Control Valve	D1VW4CKYVEP	Parker
35	3	Directional Control Valve	DS121CRI-20	Parker
36	4	Directional Control Valve Body	B12-2-12T	Parker
37	4	Directional Control Valve Coil	851019-120VAC	Parker
38	2	Flow Control	N1220S	Parker
39	6	Cord Connector	E452N30012C4L	Norstat
40	1	Hand Pump	P3A-LR	Star
41	1	Flow Control	F1620S	Parker
42	1	Velocity Fuse	R8XB-1" NPT-10 GPM	Hycon
43	1	Accumulator Stand	AS-3X20GAL-98-9695/6	Sorensen
44	3	20 Gallon ASME Piston Accumulator	A9L462003KTE/TD	Parker
45	1	Oil Pressure Switch	836T-T352J	Allen-Bradley
46	5	Drain Valve	MV820S	Parker
47	1	Gas Bottle Stand	GBS-2X90GAL-98-9695/6	Sorensen
48	2	90 Gallon Gas Bottle	B82079083T1S30	Parker
49	1	Gas Pressure Switch	10E14	United Electric
50	1	Gas Pressure Gage (0-3000 PSI)	CF1P-210A	PDI
51	1	Gas Pressure Relief Valve	2CRV-00	Hydro Seal
52	3	High Pressure Isolation Ball Valve	8VHP12NSSINA	Parker
53	1	Press Reducing Valve	PR101S30	Parker
54	1	Directional Control Valve	DS121NRM	Parker



OTE:

1) ITEMS #8 AND #20 ARE PAD LOCKABLE

2) HPU VALVE ENCLOSURE HAS A LOCKING HANDLE

3) ⧓ = NORMALLY CLOSED VALVE

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STEEL-FAB INC., TONGUE RIVER

F 5) (JOB# 98-9695-96) (CAD# STEEL49A)

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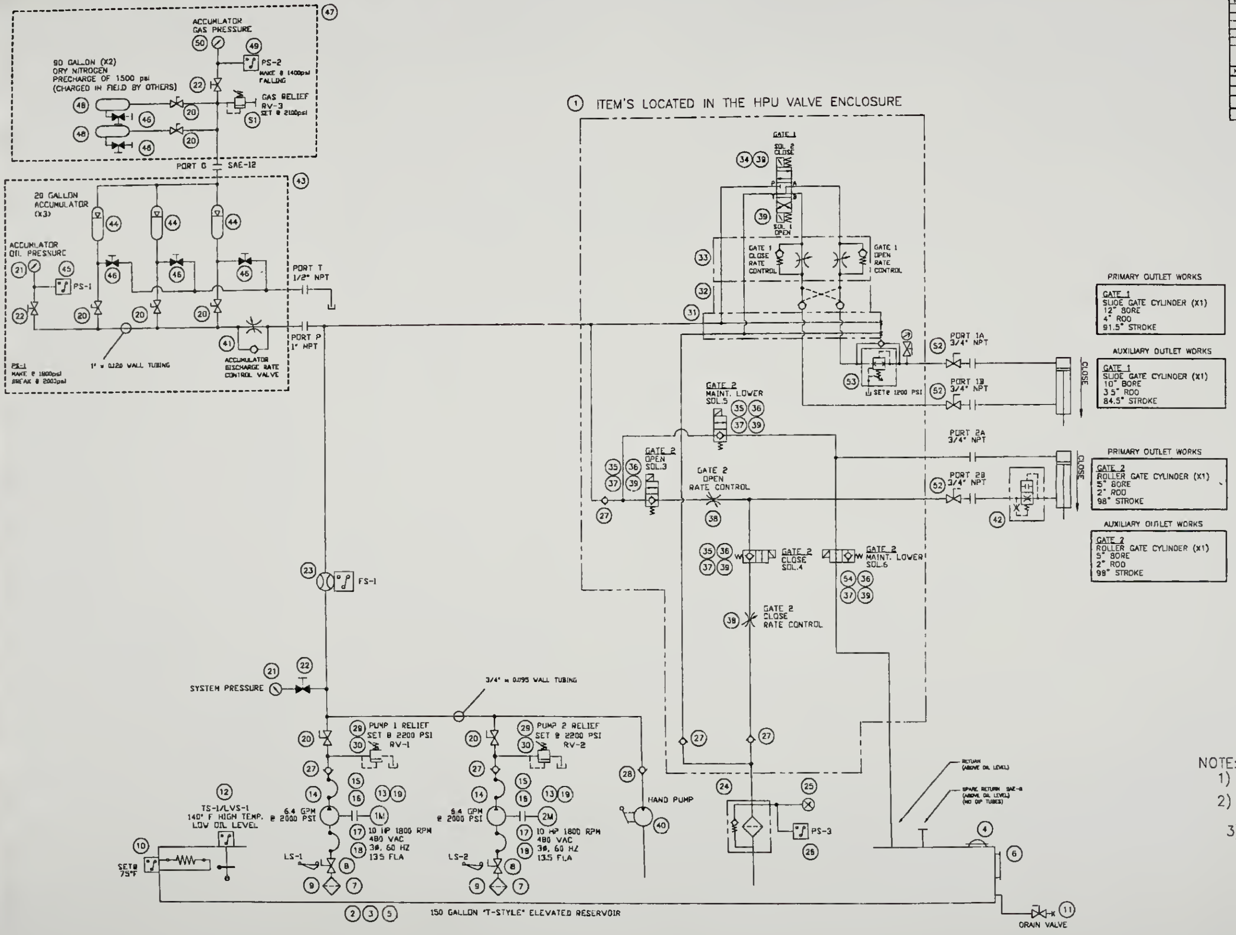
SORENSEN GOVERNOR

J31 HYDRAULIC SCHEMATIC

DRAWN BY WAVE	DATE 3/4/98	SCALE	DRAWING NO.
CHK'D	APP'D	TANGLD	HS204058

HS204058



UNIT SPECS AND SPECIAL INSTRUCTIONS	
TEST PROCEDURE:	STANDARD
WITNESS TEST:	YES
DUPLICATE UNIT:	NO
TYPE OF PLUMBING & FITTINGS:	CARBON STEEL TUBING AND PARKER SEAL-LOK FITTINGS
SIZE RESTRICTIONS:	NONE
OIL TYPE:	PETROLEUM BASED ISO 32
COOLING REQUIREMENT:	NONE
PHENOLIC/CUSTOMER LABELS:	SORENSEN STANDARD HPU LABELS
PAINT COLOR:	SORENSEN BLUE
SPECIAL INSTRUCTIONS:	ALL WIRING FROM HYDRAULIC UNIT TO ELECTRICAL BOX IS TO BE IN SEAL-TITE CONDUIT.

NOTE: ALL SYSTEM SET POINTS AND PERFORMANCE VALUES ARE ± 5% UNLESS OTHERWISE SPECIFIED ON THE SCHEMATIC.

REVISIONS

△	DATE	CHG. BY	REVISION
△1	11/11/98	CK	AS-BUILT REVISIONS
△2	4/18/01	CK	FIELD MODIFICATIONS PER ARMA

ITEM	QTY	DESCRIPTION	PRODUCT NO.	MANUFACTURER
1	1	HPU Valve Enclosure (NEMA 12)	58-304210LP	McKinstry
2	1	Drip pan/base	DP-84"X66"X2"X3/16"	Sorensen
3	1	150 Gallon JIC Style Reservoir	100150	Vescor
4	1	Filler / Breather	w/Reservoir	Vescor
5	2	End Cover	w/Reservoir	Vescor
6	1	Site Gage	G610-18-A-1	Lube Devices, Inc
7	2	Suction Strainer	10-1-100	Flo-Ezy
8	2	Low Pressure Suction Ball Valve	VP502P-16	Parker
9	2	Suction Ball Valve Limit Switch	BZE6-2RN	Microswitch
10	1	Reservoir Heater (2000 Watt)	BGS717J7S4	Watlow
11	1	Reservoir Drain Ball Valve	V500P-12	Parker
12	1	Temperature / Level Switch	TL008-140F	APCO
13	2	Motor 10HP, 480VAC,3PH, 60HZ	CM3774T-M9A	Baldor
14	2	Gear Pump 6.4GPM @ 2000PSI	PZG2AR140S1	Parker
15	2	Horiz. Motor Mount	M182472A	Magnaloy
16	2	Coupling Half	200-5/8-X-5/32	Magnaloy
17	2	Coupling Half	200-1-3/8-X-5/16	Magnaloy
18	2	Coupling Insert	270	Magnaloy
19	8	Vibration Isolation Pads	RD-2GRAY	Korfund
20	7	High Pressure Isolation Ball Valve	BVHP12SSS1NA	Parker
21	2	Pressure Gage (0-3000 PSI)	CF1P-210A	PDI
22	3	Metering Valve	MV400S	Parker
23	1	Flow Meter / Switch	682-510	Hedland
24	1	Return Filter	50AT10CN25DDL1	Parker
25	1	Return Filter Gauge	923472	Parker
26	1	Return Filter Switch	926923	Parker
27	5	Check Valve	C1220S	Parker
28	1	Check Valve	C620S	Parker
29	2	Relief Valve	RA101S30	Parker
30	2	Relief Valve Body	B10-2-8T	Parker
31	1	Subplate	AD03SPS12S	Daman Products
32	1	P.O. Check Valve	CPOM2DD	Parker
33	1	Manapak Flow Control	FM2DD	Parker
34	1	Directional Control Valve	D1VW4CNYEP	Parker
35	3	Directional Control Valve	DS121CR1-2V	Parker
36	4	Directional Control Valve Body	B12-2-12T	Parker
37	4	Directional Control Valve Coil	851019-120VAC	Parker
38	2	Flow Control	N1220S	Parker
39	6	Cord Connector	E452N30012C4L	Norstat
40	1	Hand Pump	P3A-LR	Star
41	1	Flow Control	F1620S	Parker
42	1	Velocity Fuse	RBXB-1" NPT-10 GPM	Hycon
43	1	Accumulator Stand	AS-3X20GAL-98-9695/6	Sorensen
44	3	20 Gallon ASME Piston Accumulator	A9L4620D3KTE/TB	Parker
45	1	Oil Pressure Switch	836T-T352J	Allen-Bradley
46	5	Drain Valve	MV820S	Parker
47	1	Gas Bottle Stand	GBS-2X90GAL-98-9695/6	Sorensen
48	2	90 Gallon Gas Bottle	BB20790B3T1S30	Parker
49	1	Gas Pressure Switch	10E14	United Electric
50	1	Gas Pressure Gage (0-3000 PSI)	CF1P-210A	PDI
51	1	Gas Pressure Relief Valve	2CRV-00	Hydro Seal
52	3	High Pressure Isolation Ball Valve	BVHP12NSS1NA	Parker
53	1	Press Reducing Valve	PR100S30	Parker
54	1	Directional Control Valve	DS121NRM	Parker

NOTE:

1) ITEMS #8 AND #20 ARE PAD LOCKABLE
2) HPU VALVE ENCLOSURE HAS A LOCKING HANDLE
3) ⧓ = NORMALLY CLOSED VALVE
⋈ = NORMALLY OPEN VALVE

STEEL-FAB INC., TONGUE RIVER
(SHEET 1 OF 5) (JOB# 98-9695-96) (CAD# STEEL49A)

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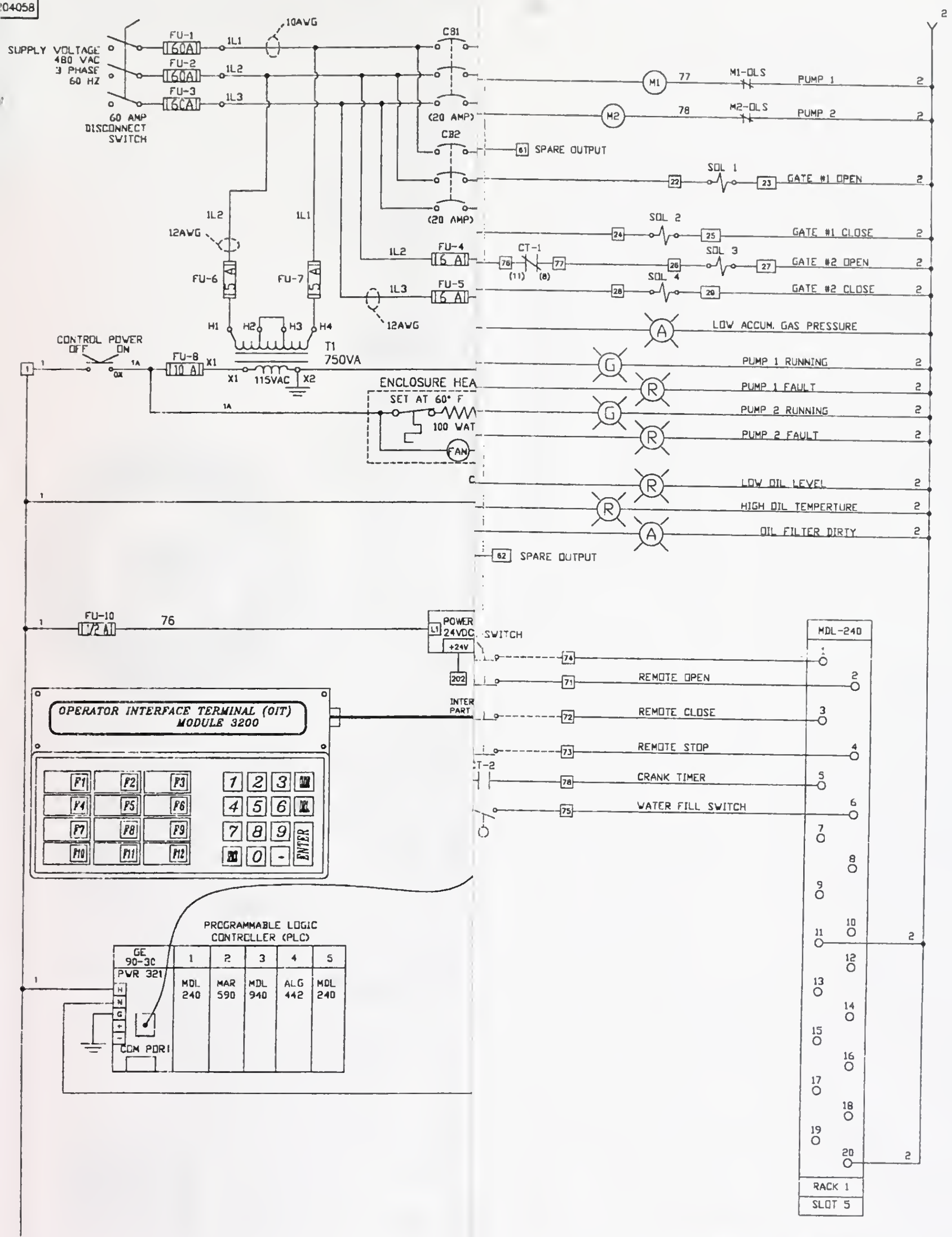
The Hope Group
SORENSEN GOVERNOR

J31
HYDRAULIC SCHEMATIC

DRAWN BY WAVE	DATE 3/4/98	SCALE	DRAWING NO. HS204058
CHK'D	APP'D		

204058



STEEL FAB, TONGUE RIVER

(JOB# 98-9695-96) (CAD# STEEL49C)

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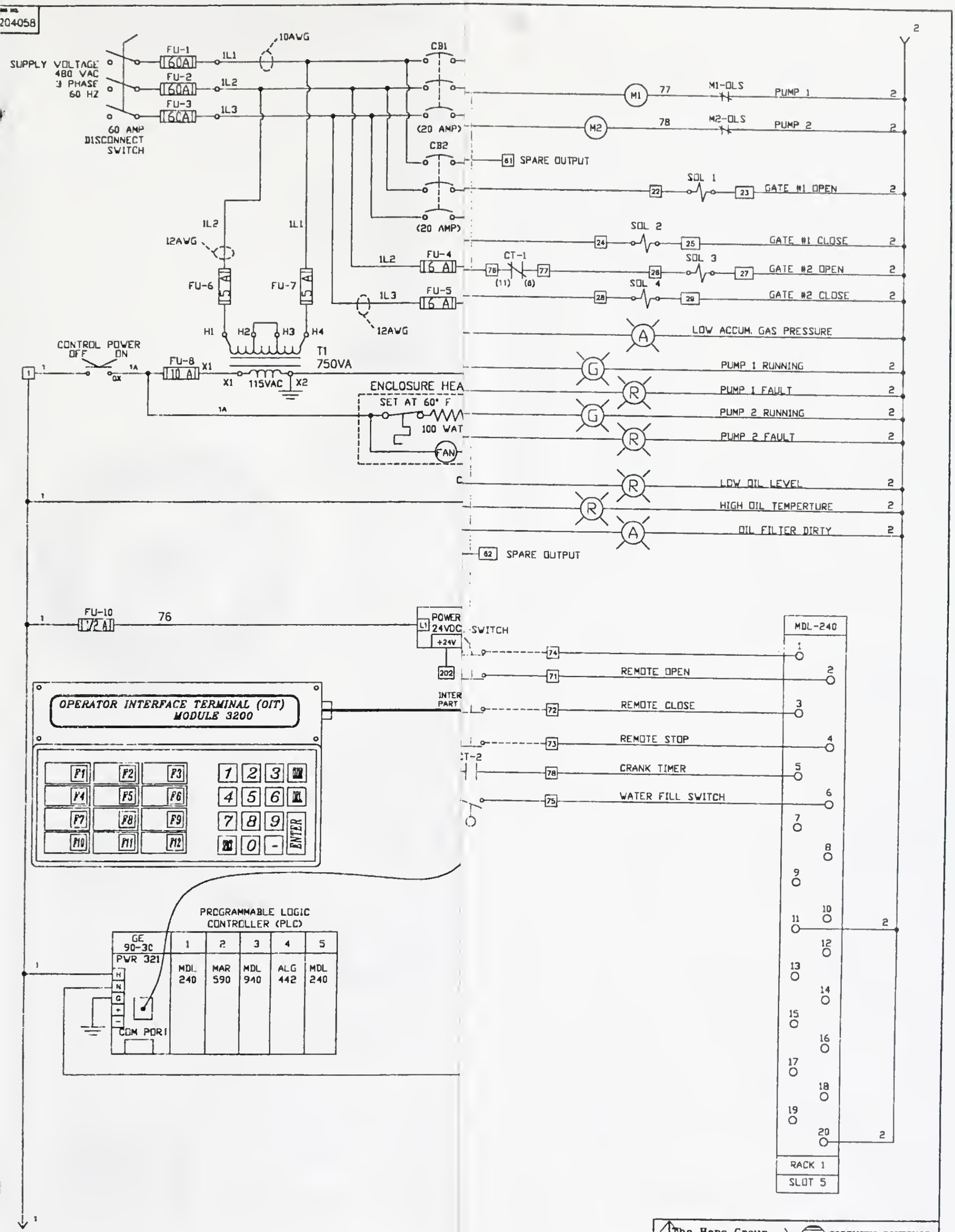
The Hope Group
70 Bearfoot Road, P.O. Box 840
Northboro, MA 01532-0840
Tel (508) 393-7660 Fax (508) 393-6042

SORENSEN GOVERNOR

J33 ELECTRICAL SCHEMATIC

DRAWN BY JIM B.	DATE 2-05-98	SCALE	DRAWING NO. ES204058
CHK'D	APP'D	TRACED	



STEEL FAB, TONGUE RIVER

(JOB# 98-9695-96) (CAD# STEEL49C)

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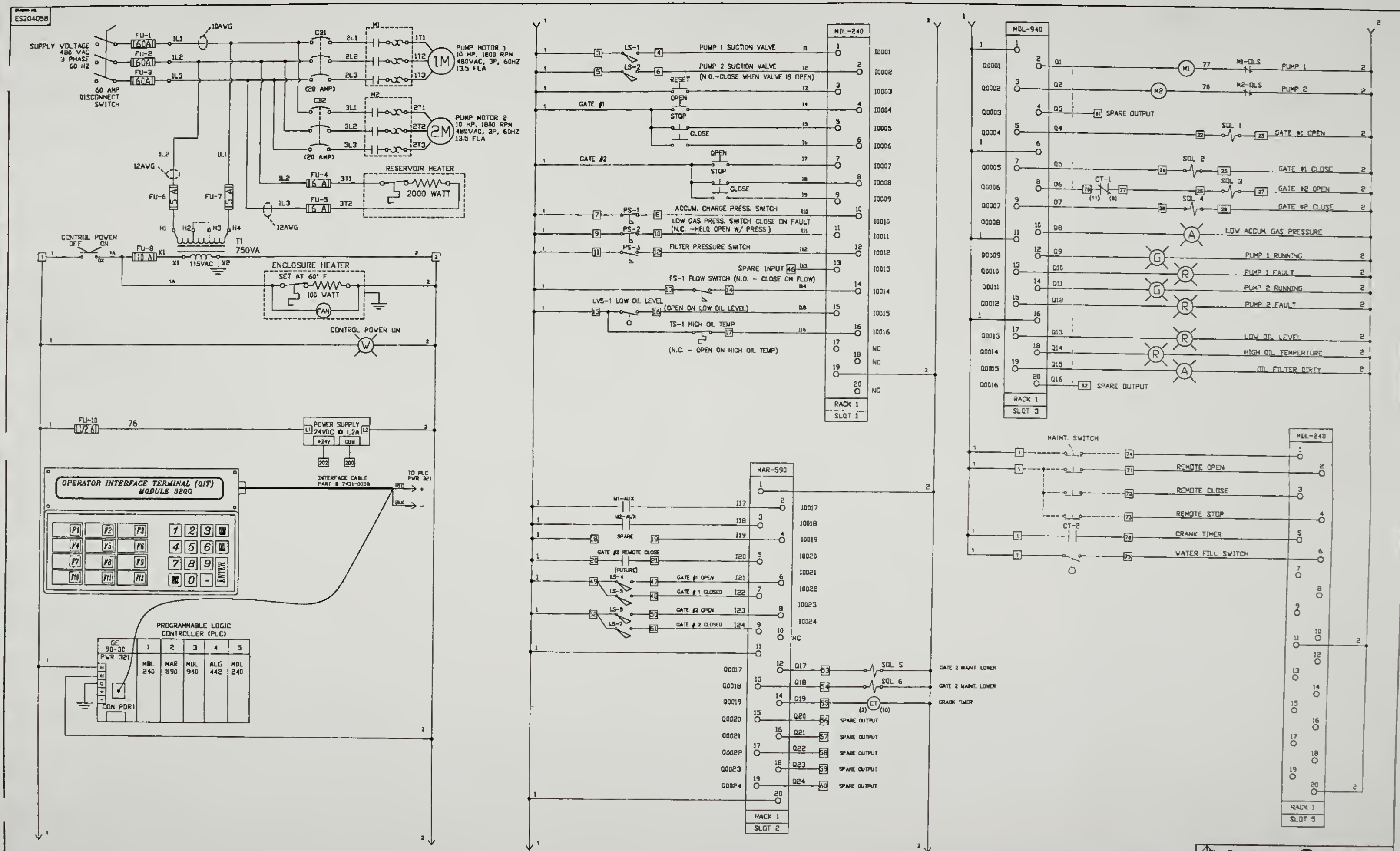
Northboro, MA 01532-0840
Tel (508) 383-7660 Fax (508) 383-6042

SORENSEN GOVERNOR

J33 ELECTRICAL SCHEMATIC

DRAWN BY JIM B.	DATE 2-05-98	SCALE	DRAWING NO.
CHK'D	APP'D	TRACED	ES204058



STEEL FAB, TONGUE RIVER
(SHEET 3) (JOB# 98-9695-98) (CAD# STEEL49C)

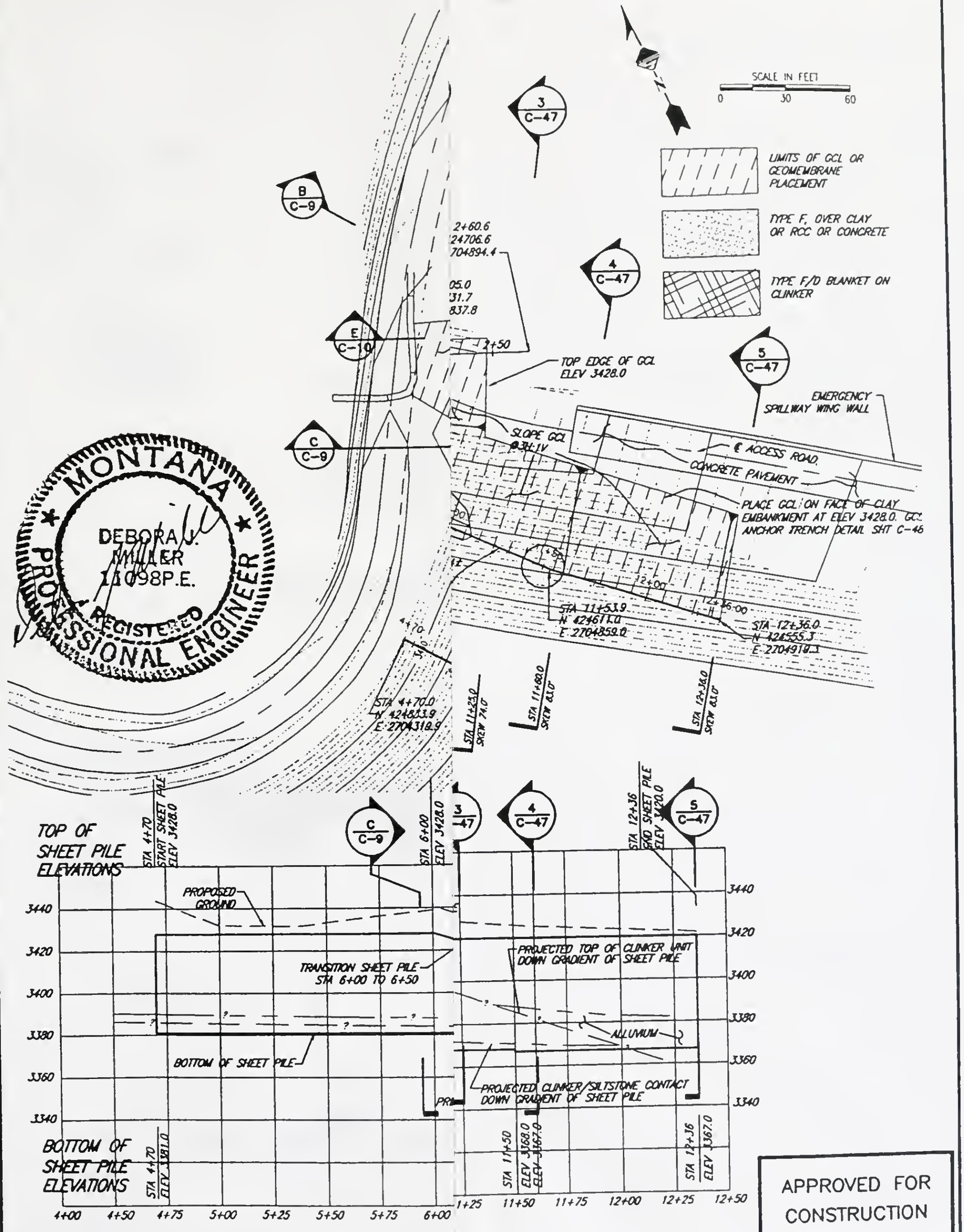
	DATE	CHG. BY	REVISION
1	11/11/98	CK	AS-BUILT REVISIONS
2	4/18/01	CK	FIELD MODIFICATIONS PER ARMA

The Rope Group

SORENSEN GOVERNOR

J33 ELECTRICAL SCHEMATIC

ES204058


SCALE IN FEET
0
30
60
LIMITS OF GCL OR GEOMEMBRANE PLACEMENT
TYPE F, OVER CLAY OR RCC OR CONCRETE
TYPE F/D BLANKET ON CLINKER
3 / C-47
4 / C-47
5 / C-47
B / C-9
C / C-9
E / C-10
2+60.6
24706.6
704894.4
05.0
31.7
837.8
2+50
TOP EDGE OF GCL ELEV 3428.0
EMERGENCY SPILLWAY WING WALL
SLOPE GCL @ 3H:1V
℄ ACCESS ROAD
CONCRETE PAVEMENT
PLACE GCL ON FACE OF CLAY EMBANKMENT AT ELEV 3428.0. GCL ANCHOR TRENCH DETAIL SHT C-46
12+00
12+36.00
STA 11+53.9 N 424611.0 E 2704859.0
STA 12+36.0 N 424555.3 E 2704919.3
4+70
STA 4+70.0 N 424853.9 E 2704319.9
STA 11+23.0 SKEW 74.0
STA 11+60.0 SKEW 83.0
STA 12+36.0 SKEW 83.0
TOP OF SHEET PILE ELEVATIONS
STA 4+70 START SHEET PILE ELEV 3428.0
STA 6+00 ELEV 3428.0
STA 12+36 END SHEET PILE ELEV 3420.0
PROPOSED GROUND
TRANSITION SHEET PILE STA 6+00 TO 6+50
BOTTOM OF SHEET PILE
PROJECTED TOP OF CLINKER UNIT DOWN GRADIENT OF SHEET PILE
ALLUVIUM
PROJECTED CLINKER/SILTSTONE CONTACT DOWN GRADIENT OF SHEET PILE
3440
3420
3400
3380
3360
3340
BOTTOM OF SHEET PILE ELEVATIONS
STA 4+70 ELEV 3381.0
STA 11+50 ELEV 3368.0 ELEV 3367.0
STA 12+36 ELEV 3367.0
4+00
4+50
4+75
5+00
5+25
5+50
5+75
6+00
11+25
11+50
11+75
12+00
12+25
12+50

MONTANA
DEBORA J. MILLER
11098P.E.
REGISTERED PROFESSIONAL ENGINEER

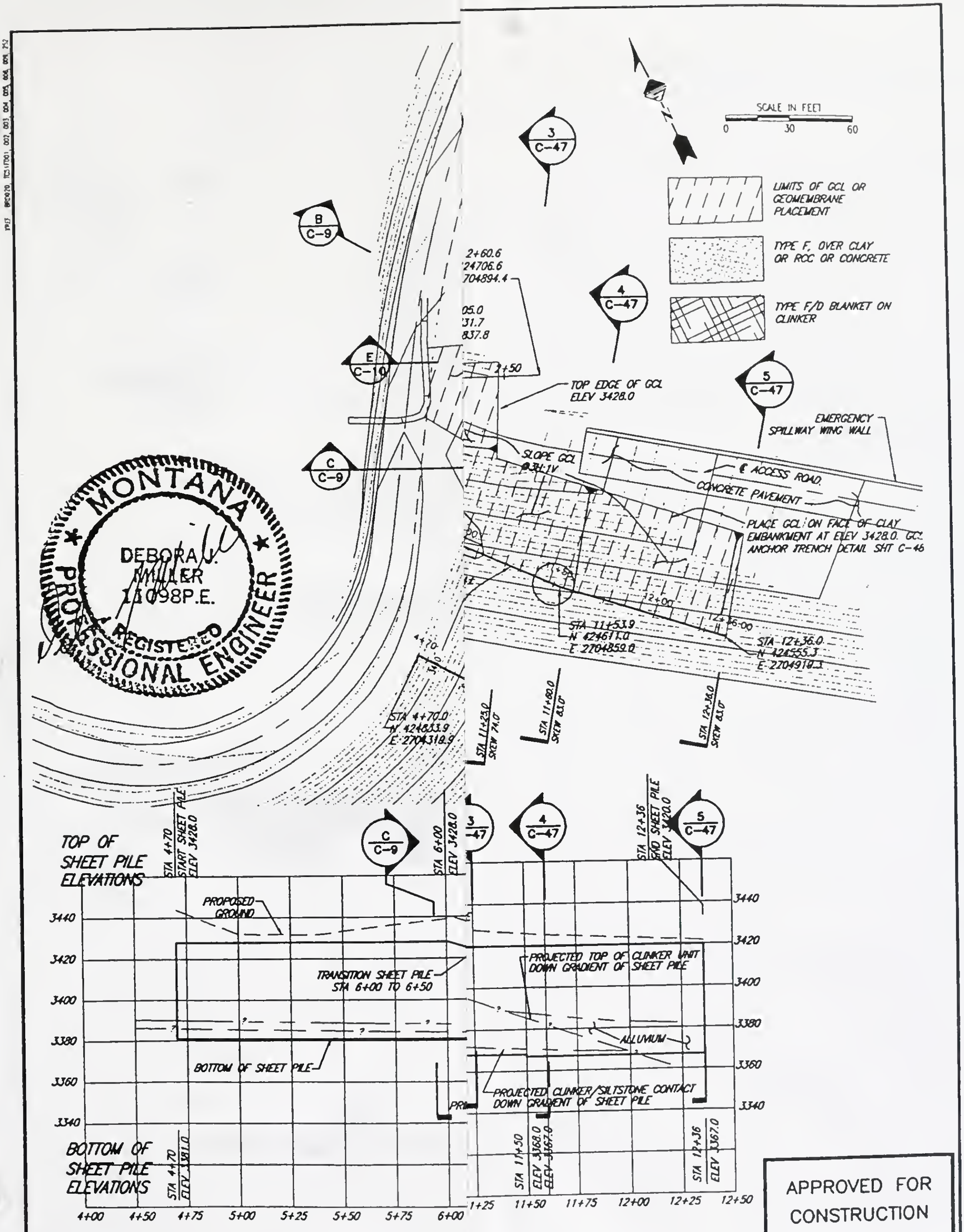
APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

ABUTMENT PIPING CONTROL MEASURES
PLAN & PROFILE

J35

SHEET
C-45


SCALE IN FEET
0
30
60
N
LIMITS OF GCL OR GEOMEMBRANE PLACEMENT
TYPE F, OVER CLAY OR RCC OR CONCRETE
TYPE F/D BLANKET ON CLINKER
3 / C-47
4 / C-47
5 / C-47
B / C-9
E / C-10
C / C-9
2+60.6
24706.6
704894.4
05.0
31.7
837.8
2+50
TOP EDGE OF GCL ELEV 3428.0
SLOPE GCL @3:1V
EMERGENCY SPILLWAY WING WALL
℄ ACCESS ROAD
CONCRETE PAVEMENT
PLACE GCL ON FACE OF CLAY EMBANKMENT AT ELEV 3428.0. GCL ANCHOR TRENCH DETAIL SHT C-46
12+00
STA 11+53.9
N 424611.0
E 2704859.0
STA 12+36.0
N 424555.3
E 2704919.3
4+70
STA 4+70.0
N 424833.9
E 2704319.9
STA 11+23.0 SKEW 74.0
STA 11+80.0 SKEW 83.0
STA 12+38.0 SKEW 83.0
TOP OF SHEET PILE ELEVATIONS
STA 4+70 START SHEET PILE ELEV 3428.0
STA 6+00 ELEV 3428.0
STA 12+36 END SHEET PILE ELEV 3420.0
PROPOSED GROUND
TRANSITION SHEET PILE STA 6+00 TO 6+50
PROJECTED TOP OF CLINKER UNIT DOWN GRADIENT OF SHEET PILE
ALLUVIUM
BOTTOM OF SHEET PILE
PROJECTED CLINKER/SILTSTONE CONTACT DOWN GRADIENT OF SHEET PILE
PRI
3440
3420
3400
3380
3360
3340
BOTTOM OF SHEET PILE ELEVATIONS
STA 4+70 ELEV 3381.0
STA 11+50 ELEV 3368.0 ELEV 3367.0
STA 12+36 ELEV 3367.0
4+00
4+50
4+75
5+00
5+25
5+50
5+75
6+00
11+25
11+50
11+75
12+00
12+25
12+50

MONTANA
DEBORA J. MILLER
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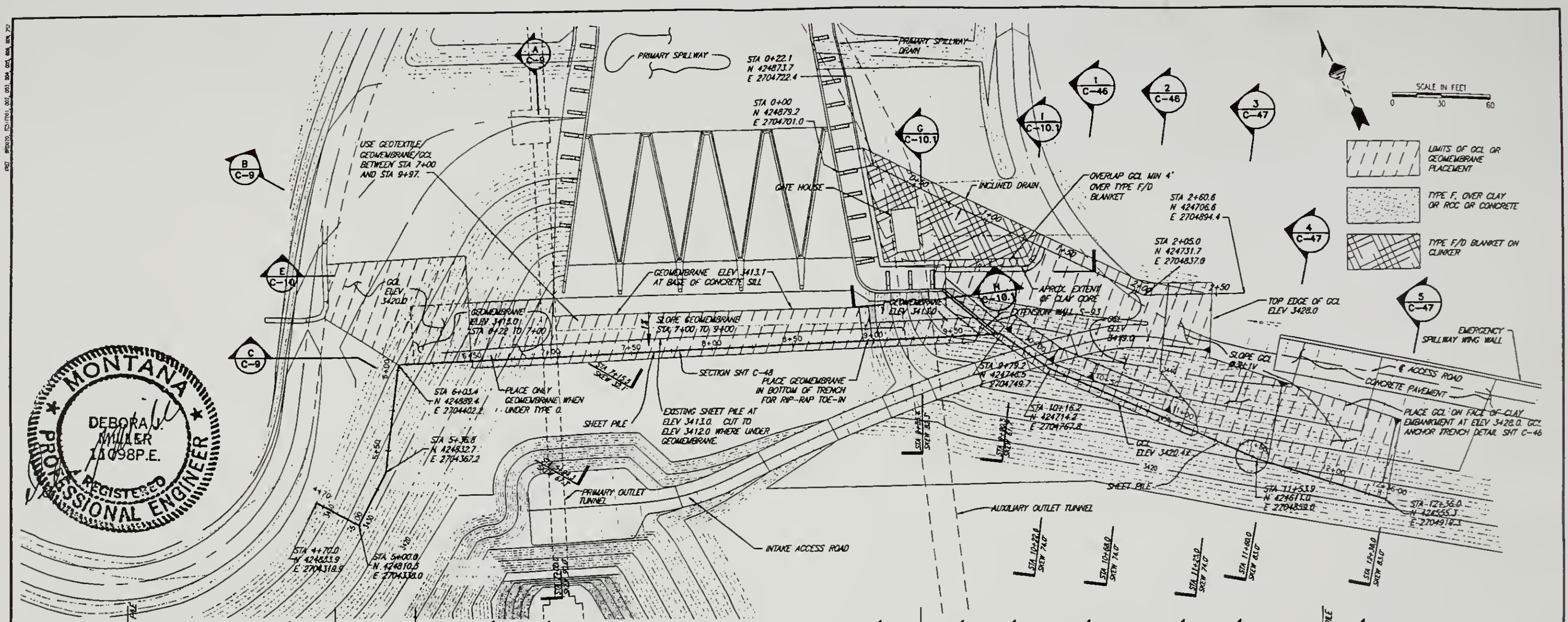
NO	BY	DATE	REVISION DESCRIPTION

ABUTMENT PIPING CONTROL MEASURES
PLAN & PROFILE

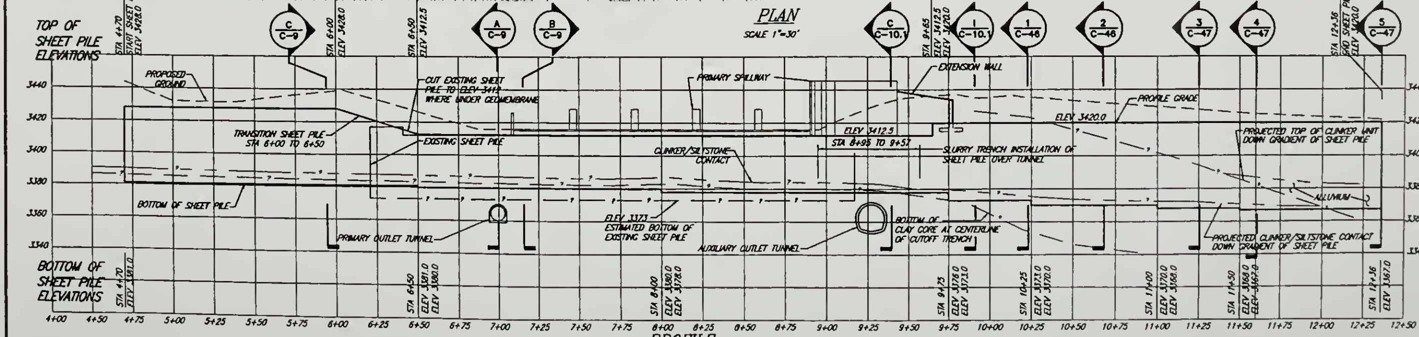
J35

SHEET
C-45


PRIMARY SPILLWAY
PRIMARY SPILLWAY DRAIN
STA 0+22.1 N 424873.7 E 2704722.4
STA 0+00 N 424879.2 E 2704701.0
USE GEOTEXTILE/ GEOMEMBRANE/GCL BETWEEN STA 7+00 AND STA 9+97.
GATE HOUSE
INCLINED DRAIN
OVERLAP GCL MIN 4' OVER TYPE F/D BLANKET
STA 2+60.6 N 424706.6 E 2704894.4
STA 2+05.0 N 424731.7 E 2704837.0
GCL ELEV 3420.0
GEOMEMBRANE ELEV 3413.1 AT BASE OF CONCRETE SILL
GEOMEMBRANE ELEV 3413.0 STA 6+22 TO 7+00
SLOPE GEOMEMBRANE STA 7+00 TO 9+00
GEOMEMBRANE ELEV 3413.0
APROX. EXTENT OF CLAY CORE
EXTENSION WALL S-93
GCL ELEV 3419.0
TOP EDGE OF GCL ELEV 3428.0
EMERGENCY SPILLWAY WING WALL
SLOPE GCL 3.3H:1V
℄ ACCESS ROAD
CONCRETE PAVEMENT
PLACE GCL ON FACE OF CLAY EMBANKMENT AT ELEV 3428.0. GCL ANCHOR TRENCH DETAIL SHT C-46
STA 9+79.2 N 424740.5 E 2704749.7
SECTION SHT C-48
PLACE GEOMEMBRANE IN BOTTOM OF TRENCH FOR RIP-RAP TOE-IN
STA 6+03.4 N 424889.4 E 2704402.2
PLACE ONLY GEOMEMBRANE WHEN UNDER TYPE O.
SHEET PILE
EXISTING SHEET PILE AT ELEV 3413.0. CUT TO ELEV 3412.0 WHERE UNDER GEOMEMBRANE.
STA 10+16.2 N 424714.2 E 2704767.8
GCL ELEV 3420.4±
SHEET PILE
STA 11+53.9 N 424611.0 E 2704859.0
STA 12+36.0 N 424555.3 E 2704918.3
STA 5+36.8 N 424832.7 E 2704367.2
PRIMARY OUTLET TUNNEL
AUXILIARY OUTLET TUNNEL
INTAKE ACCESS ROAD
STA 4+70.0 N 424833.9 E 2704318.9
STA 5+00.0 N 424810.5 E 2704338.0
LIMITS OF GCL OR GEOMEMBRANE PLACEMENT
TYPE F, OVER CLAY OR ROC OR CONCRETE
TYPE F/D BLANKET ON CLINKER
SCALE IN FEET
0 30 60
A C-9
B C-9
C C-9
E C-10
G C-10.1
H C-10.1
1 C-10.1
1 C-46
2 C-46
3 C-47
4 C-47
5 C-47

PLAN

SCALE 1"=30'


TOP OF SHEET PILE ELEVATIONS
STA 4+70 START SHEET PILE ELEV 3428.0
STA 6+00 ELEV 3428.0
STA 6+50 ELEV 3412.5
STA 9+65 ELEV 3412.5 ELEV 3420.0
STA 12+36 END SHEET PILE ELEV 3420.0
PROPOSED GROUND
CUT EXISTING SHEET PILE TO ELEV 3412 WHERE UNDER GEOMEMBRANE
PRIMARY SPILLWAY
EXTENSION WALL
PROFILE GRADE
ELEV 3420.0
TRANSITION SHEET PILE STA 6+00 TO 6+50
EXISTING SHEET PILE
ELEV 3412.5
STA 8+95 TO 9+57
CLINKER/SILTSTONE CONTACT
SLURRY TRENCH INSTALLATION OF SHEET PILE OVER TUNNEL
PROJECTED TOP OF CLINKER UNIT DOWN GRADIENT OF SHEET PILE
ALLUVIUM
BOTTOM OF SHEET PILE
PRIMARY OUTLET TUNNEL
ELEV 3373 ESTIMATED BOTTOM OF EXISTING SHEET PILE
AUXILIARY OUTLET TUNNEL
BOTTOM OF CLAY CORE AT CENTERLINE OF CUTOFF TRENCH
PROJECTED CLINKER/SILTSTONE CONTACT DOWN GRADIENT OF SHEET PILE
BOTTOM OF SHEET PILE ELEVATIONS
STA 4+70 ELEV 3381.0
STA 6+50 ELEV 3381.0 ELEV 3380.0
STA 8+00 ELEV 3380.0 ELEV 3378.0
STA 9+75 ELEV 3374.0 ELEV 3373.0
STA 10+25 ELEV 3373.0 ELEV 3370.0
STA 11+00 ELEV 3370.0 ELEV 3368.0
STA 11+50 ELEV 3368.0 ELEV 3367.0
STA 12+36 ELEV 3367.0
3440
3420
3400
3380
3360
3340
4+00 4+50 4+75 5+00 5+25 5+50 5+75 6+00 6+25 6+50 6+75 7+00 7+25 7+50 7+75 8+00 8+25 8+50 8+75 9+00 9+25 9+50 9+75 10+00 10+25 10+50 10+75 11+00 11+25 11+50 11+75 12+00 12+25 12+50

PROFILE

SCALE 1"=30'

MONTANA
DEBORA J. MILLER
11098P.E.
REGISTERED PROFESSIONAL ENGINEER

APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

STN DRAWN	DJM DESIGNED	DJM CHECKED
DJM APPROVED	9/98 DATE	141.9501 PROJECT NO

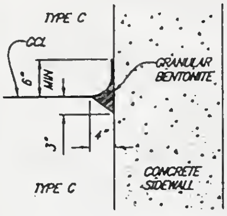
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By
ESA Consultants Inc.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

WEST ABUTMENT PIPING CONTROL MEASURES
PLAN & PROFILE

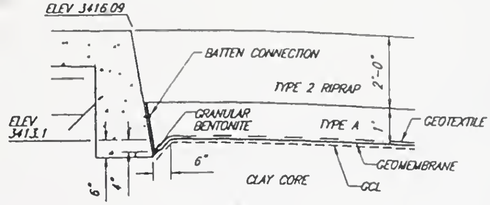
J35

SHEET
C-45

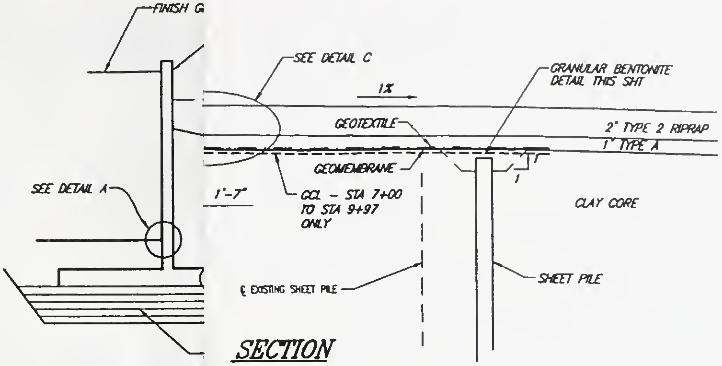


DETAIL A
SCALE: 1" = 1'

NOTE: REFER TO SHT C-45
FOR EXTENT OF GCL
WALL CONNECTION.

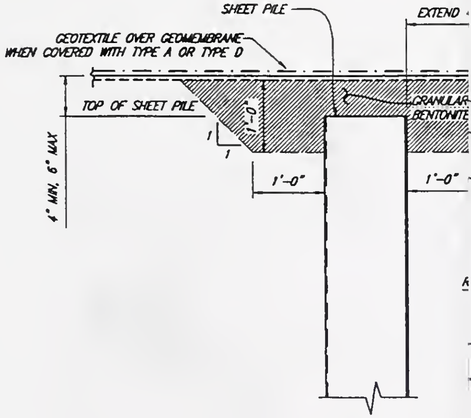


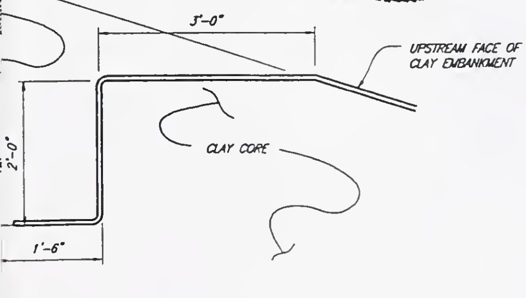
DETAIL C
SCALE: 1" = 2'



SECTION
SE…BRANE CONNECTIONS
GEOMEMBRANE A…Y SPILLWAY CENTERLINE
SCAL… SCALE: 1" = 5'

DEBORA
MILLER
11098P.E.





DETAIL
TYPE 1 SHEET PILE CON…

SCALE: 1" = 1'-0"

STA 6+50 TO 9+65
AND
STA 9+78 TO 11+10

DETAIL
…NCHOR TRENCH
…ALE: 1" = 1'-0"

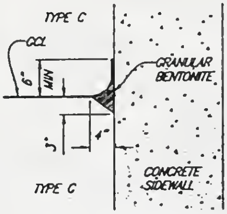
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

ABUTMENT PIPING CONTROL MEASURES
SECTIONS AND DETAILS

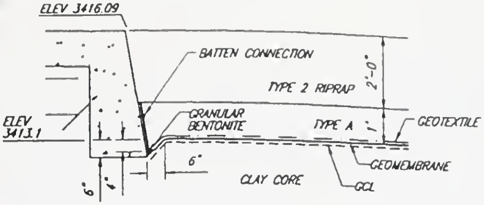
J37

SHEET
C-48

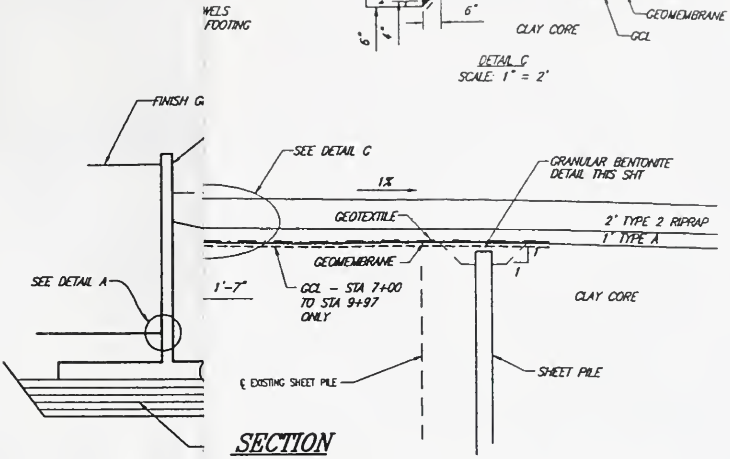


DETAIL A
SCALE: 1" = 1'

NOTE: REFER TO SHT C-45 FOR EXTENT OF GCL WALL CONNECTION.



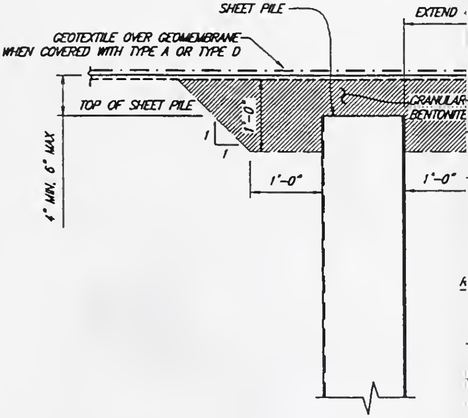
DETAIL C
SCALE: 1" = 2'



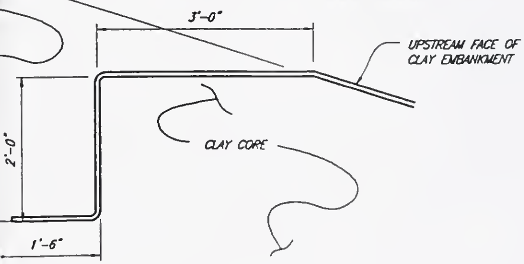
SECTION
BRANE CONNECTIONS
Y SPILLWAY CENTERLINE
SCALE: 1" = 5'

SE
GEOMEMBRANE A
SCAL

MONTANA
DEBORA
MILLER
11098P.E.
REGISTERED
PROFESSIONAL ENGINEER



DETAIL
TYPE 1 SHEET PILE CON
SCALE: 1" = 1'-0"
STA 6+50 TO 9+65
AND
STA 9+78 TO 11+10



DETAIL
NCHOR TRENCH
ALE: 1" = 1'-0"

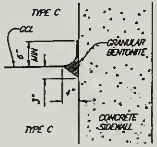
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

ABUTMENT PIPING CONTROL MEASURES
SECTIONS AND DETAILS

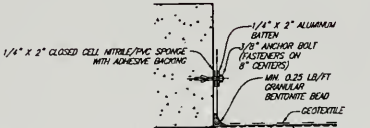
J37

SHEET
C-48

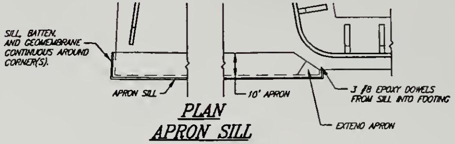


DETAIL A
SCALE: 1" = 1'

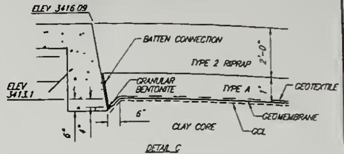
NOTE: REFER TO SHT C-45 FOR EXTENT OF GCL WALL CONNECTION.


1/4" X 2" ALUMINUM BATTEN
3/8" ANCHOR BOLT (FASTENERS ON 8" CENTERS)
1/4" X 2" CLOSED CELL NITRILE/PVC SPONGE WITH ADHESIVE BACKING
MIN. 0.25 LB/FT GRANULAR BENTONITE BEAD
GEOTEXTILE
GEOMEMBRANE
GCL
GCL BELOW GRANULAR BENTONITE BEAD

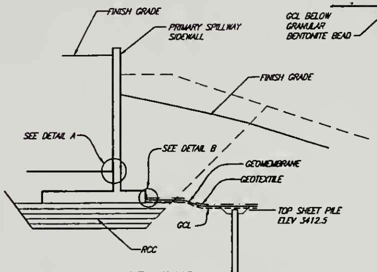
DETAIL B
SCALE: 1" = 1'


SILL, BATTEN, AND GEOMEMBRANE CONTINUOUS AROUND CORNER(S).
APRON SILL
10' APRON
3 /8 EPOXY DOWELS FROM SILL INTO FOOTING
EXTEND APRON

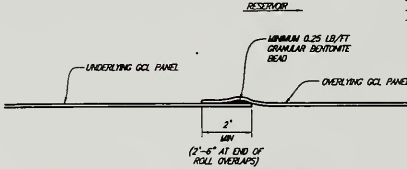
PLAN APRON SILL
NOT TO SCALE



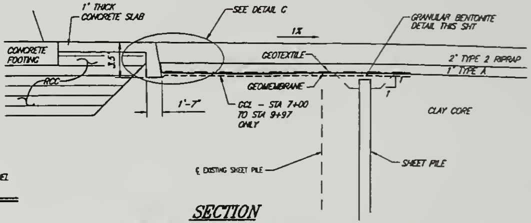
DETAIL C
SCALE: 1" = 2'



SECTION GEOMEMBRANE AND GCL PLACEMENT
SCALE: 1" = 10'

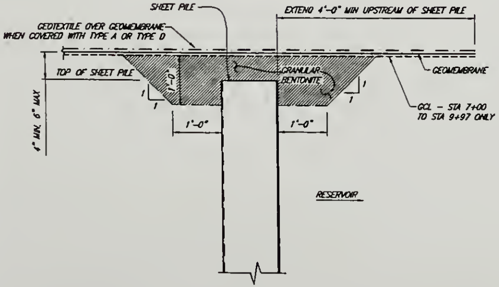

RESERVOIR
MINIMUM 0.25 LB/FT GRANULAR BENTONITE BEAD
UNDERLYING GCL PANEL
OVERLYING GCL PANEL
2"
MIN
(2'-6" AT END OF ROLL OVERLAPS)

TYPICAL GCL OVERLAP DETAIL
SCALE: 1" = 2'



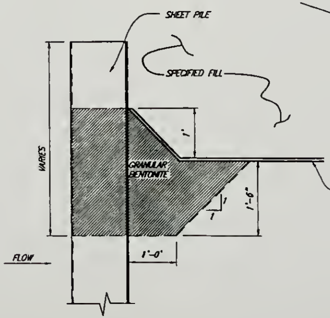
SECTION GEOMEMBRANE CONNECTIONS AT PRIMARY SPILLWAY CENTERLINE
SCALE: 1" = 5'

DEBORA MILLER
11098P.E.


SHEET PILE
EXTEND 4'-0" MIN UPSTREAM OF SHEET PILE
GEOTEXTILE OVER GEOMEMBRANE WHEN COVERED WITH TYPE A OR TYPE D
TOP OF SHEET PILE
1'-0"
GRANULAR BENTONITE
GEOMEMBRANE
1
1
1
1
4" MIN, 6" MAX
1'-0"
1'-0"
GCL - STA 7+00 TO STA 9+97 ONLY
RESERVOIR

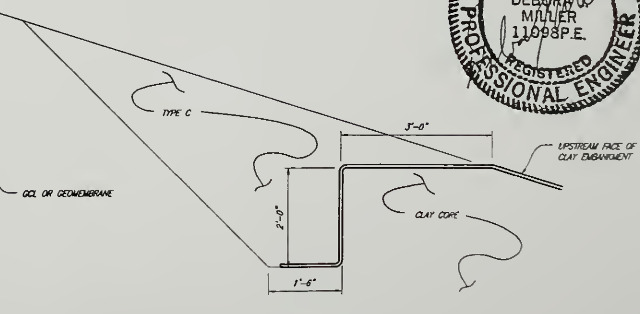
DETAIL TYPE 1 SHEET PILE CONNECTION
SCALE: 1" = 1'-0"

STA 6+50 TO 9+65
AND
STA 9+78 TO 11+10



DETAIL TYPE 2 SHEET PILE CONNECTION
SCALE: 1" = 1'-0"

STA 6+04 TO 6+50,
STA 9+65 TO 9+78
AND
STA 11+10 TO 12+36



DETAIL GCL ANCHOR TRENCH
SCALE: 1" = 1'-0"

APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

MAK/SM DRAWN
ACJ DESIGNED
CHECKED
APPROVED
9/98 DATE
141.9501 PROJECT NO.

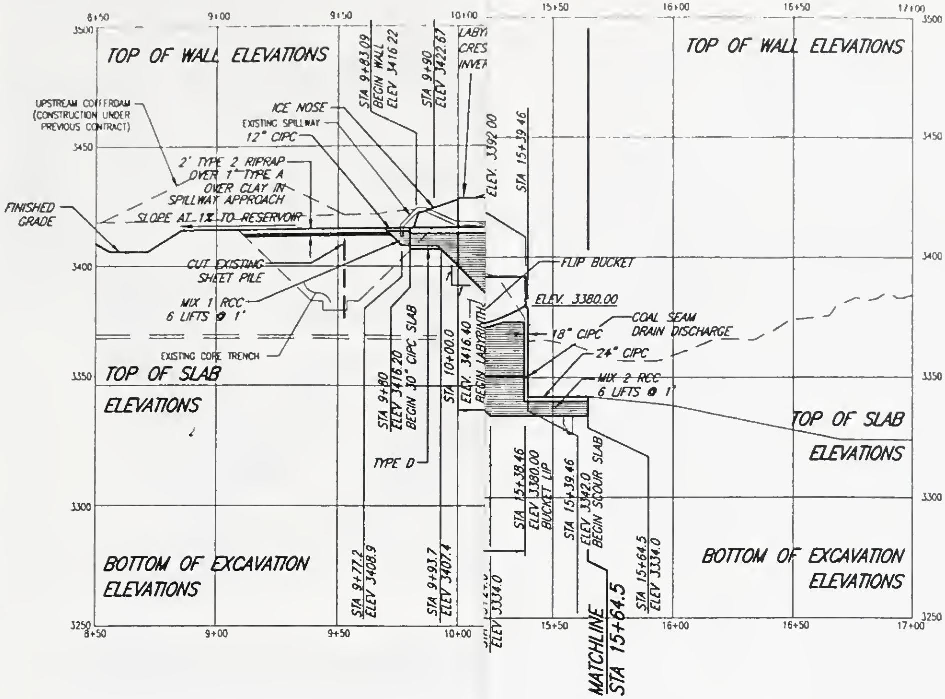
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

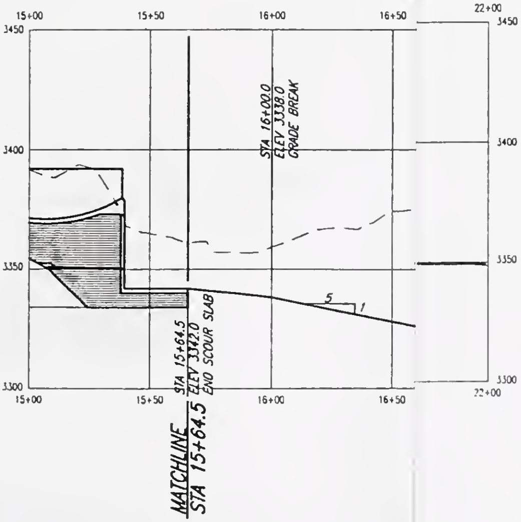
Prepared By:
ESA Consultants Inc.
815 West Mendenhall, Suite C-1, Bozeman MT. 59715

WEST ABUTMENT PIPING CONTROL MEASURES
SECTIONS AND DETAILS

J37

SHEET C-48




15+00
15+50
16+00
16+50
22+00
3450
3400
3350
3300
STA 16+00.0 ELEV 3338.0 GRADE BREAK
5
1
STA 15+64.5 ELEV 3342.0 END SCOUR SLAB
MATCHLINE STA 15+64.5

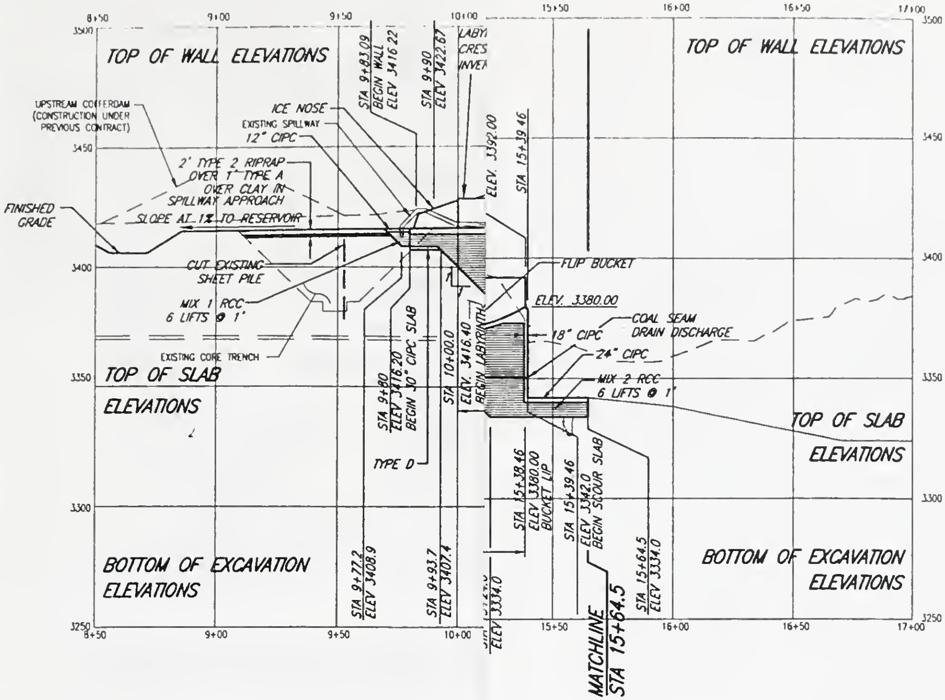
APPROVED FOR CONSTRUCTION

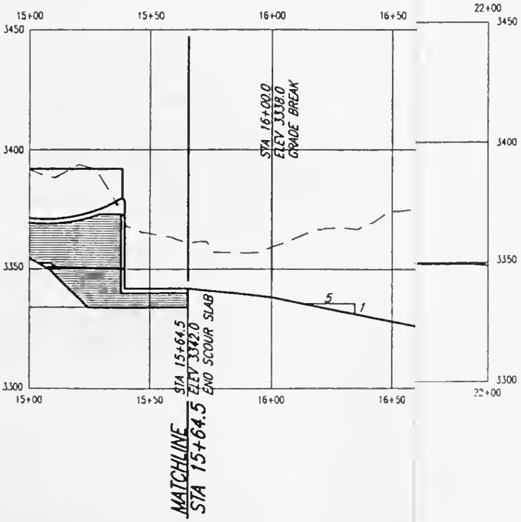
NO	BY	DATE	REVISION DESCRIPTION

PRIMARY SPILLWAY
PROFILE

J39

SHEET
C-5




STA 16+00.0 ELEV 3338.0 GRADE BREAK
STA 15+64.5 ELEV 3342.0 END SCOUR SLAB
5
1
MATCHLINE STA 15+64.5
15+00
15+50
16+00
16+50
22+00
3450
3400
3350
3300

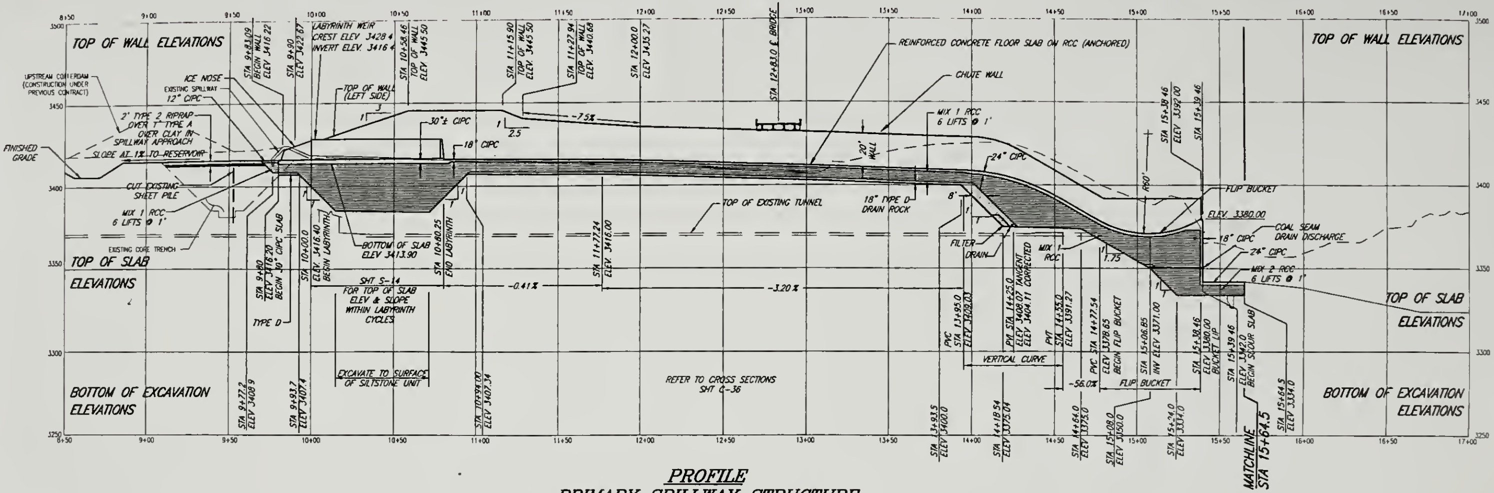
APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

PRIMARY SPILLWAY
PROFILE

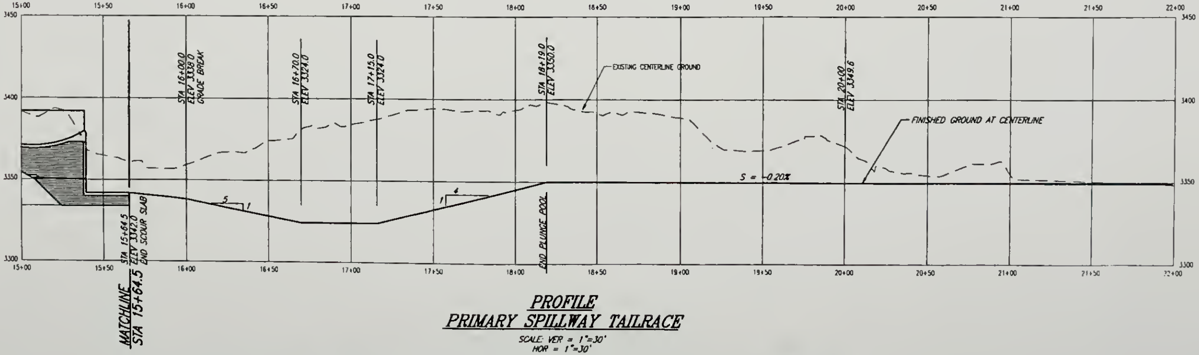
J39

SHEET
C-5


TOP OF WALL ELEVATIONS
TOP OF SLAB ELEVATIONS
BOTTOM OF EXCAVATION ELEVATIONS
UPSTREAM COFFERDAM (CONSTRUCTION UNDER PREVIOUS CONTRACT)
FINISHED GRADE
2' TYPE 2 RIPRAP OVER 1' TYPE A OVER CLAY IN SPILLWAY APPROACH
SLOPE AT 1% TO RESERVOIR
ICE NOSE
EXISTING SPILLWAY 12" CIPC
CUT EXISTING SHEET PILE
MIX 1 RCC 6 LIFTS @ 1'
EXISTING CORE TRENCH
LABYRINTH WEIR CREST ELEV 3428.4 INVERT ELEV. 3416.4
TOP OF WALL (LEFT SIDE)
30"± CIPC
18" CIPC
BOTTOM OF SLAB ELEV 3413.90
SHT S-14 FOR TOP OF SLAB ELEV & SLOPE WITHIN LABYRINTH CYCLES
EXCAVATE TO SURFACE OF SILTSTONE UNIT
TYPE D
-0.41%
-7.5%
-3.20%
STA 12+83.0 ℄ BRIDGE
REINFORCED CONCRETE FLOOR SLAB ON RCC (ANCHORED)
CHUTE WALL
MIX 1 RCC 6 LIFTS @ 1'
20' WALL
24" CIPC
TOP OF EXISTING TUNNEL
18" TYPE D DRAIN ROCK
FILTER DRAIN
MIX 1 RCC
VERTICAL CURVE
-56.0%
FLIP BUCKET
ELEV. 3380.00
18" CIPC
24" CIPC
COAL SEAM DRAIN DISCHARGE
MIX 2 RCC 6 LIFTS @ 1'
R60'
REFER TO CROSS SECTIONS SHT C-36
STA 9+83.09 BEGIN WALL ELEV 3416.22
STA 9+90 ELEV 3422.67
STA 10+58.46 TOP OF WALL ELEV 3445.50
STA 11+15.90 TOP OF WALL ELEV. 3445.50
STA 11+27.94 TOP OF WALL ELEV. 3440.68
STA 12+00.0 ELEV 3435.27
STA 15+38.46 ELEV 3392.00
STA 15+39.46
STA 9+80 ELEV 3416.20 BEGIN 30" CIPC SLAB
STA 10+00.0 ELEV. 3416.40 BEGIN LABYRINTH
STA 10+80.25 END LABYRINTH
STA 11+77.24 ELEV. 3416.00
PVC STA 13+95.0 ELEV 3409.03
PVI STA 14+25.0 ELEV 3408.07 TANGENT ELEV 3404.11 CORRECTED
PVT STA 14+35.0 ELEV 3391.27
PVC STA 14+77.54 ELEV 3378.65 BEGIN FLIP BUCKET
STA 15+06.85 INV ELEV 3371.00
STA 15+38.46 ELEV 3380.00 BUCKET LIP
STA 15+39.46 ELEV 3342.0 BEGIN SCOUR SLAB
STA 9+77.2 ELEV 3408.9
STA 9+93.7 ELEV 3407.4
STA 10+94.00 ELEV 3407.34
STA 13+93.5 ELEV 3400.0
STA 14+18.54 ELEV 3375.04
STA 14+64.0 ELEV 3375.0
STA 15+08.0 ELEV 3350.0
STA 15+24.0 ELEV 3334.0
STA 15+64.5 ELEV 3334.0
MATCHLINE STA 15+64.5

PROFILE
PRIMARY SPILLWAY STRUCTURE

SCALE: VER = 1"=30'
HOR = 1"=30'



PROFILE
PRIMARY SPILLWAY TAILRACE

SCALE: VER = 1"=30'
HOR = 1"=30'

APPROVED FOR CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

MAK DRAWN — WRK SM DESIGNED — STN CHECKED
WRK APPROVED — 7/97 DATE — 141.0501 PROJECT NO

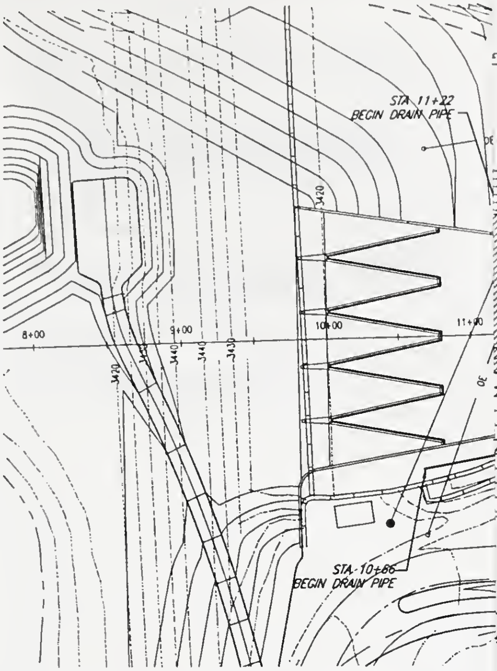
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

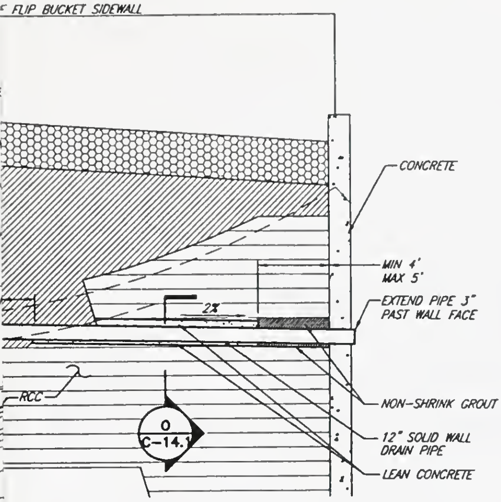
Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

PRIMARY SPILLWAY
PROFILE

J39

SHEET C-5

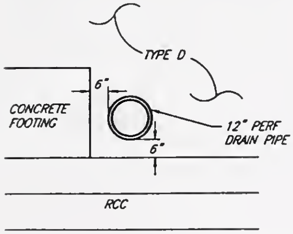




SECTION
LL DRAIN DISCHARGE PIPE

SCALE: 1" = 5'

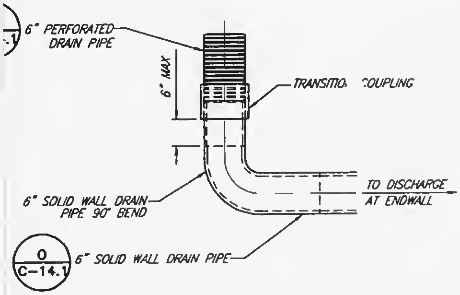
① PS STA 14+08 TO 14+13± INSTALL SOLID WALL DRAIN PIPE. EXTE
END OF PIPE TWO FEET BEYOND FACE OF SLOPE. SECURE 1/2" M
SS HARDWARE CLOTH TO END OF PIPE WITH SS BAND.



N
C-11

DETAIL
WALL DRAIN

SCALE: 1/2" = 1'



Q
C-14.1

DETAIL
COAL SEAM DRAIN ELBOW

SCALE: 1" = 1'

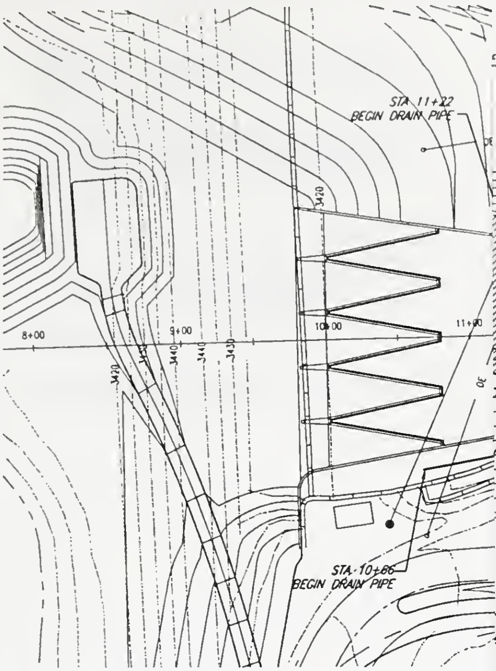
APPROVED FOR
CONSTRUCTION

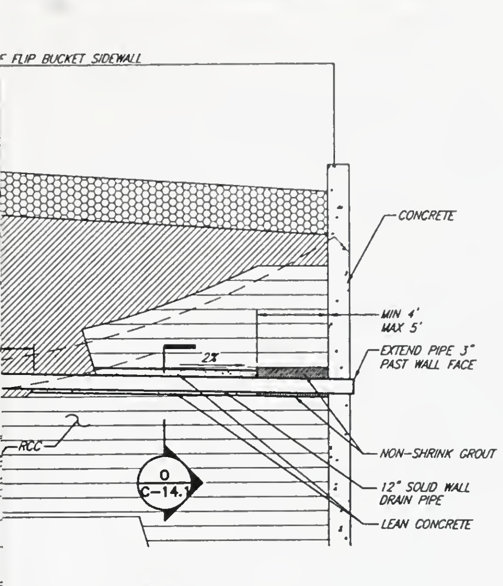
NO	BY	DATE	REVISION DESCRIPTION

MARY SPILLWAY DRAINAGE SYSTEM
PLAN, SECTIONS AND DETAILS

J41

SHEET
C-14.1

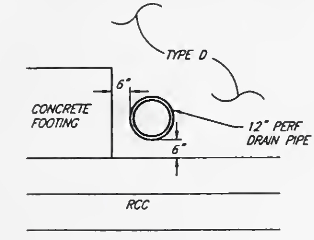




SECTION
LL DRAIN DISCHARGE PIPE

SCALE: 1" = 5'

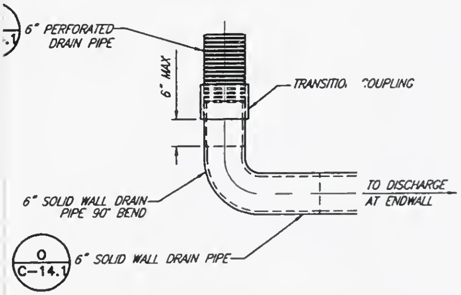
① PS STA 14+08 TO 14+13± INSTALL SOLID WALL DRAIN PIPE. EXTE
END OF PIPE TWO FEET BEYOND FACE OF SLOPE. SECURE 1/2" M
SS HARDWARE CLOTH TO END OF PIPE WITH SS BAND.



N
C-11

DETAIL
WALL DRAIN

SCALE: 1/2" = 1'



Q
C-14.1

DETAIL
COAL SEAM DRAIN ELBOW

SCALE: 1" = 1'

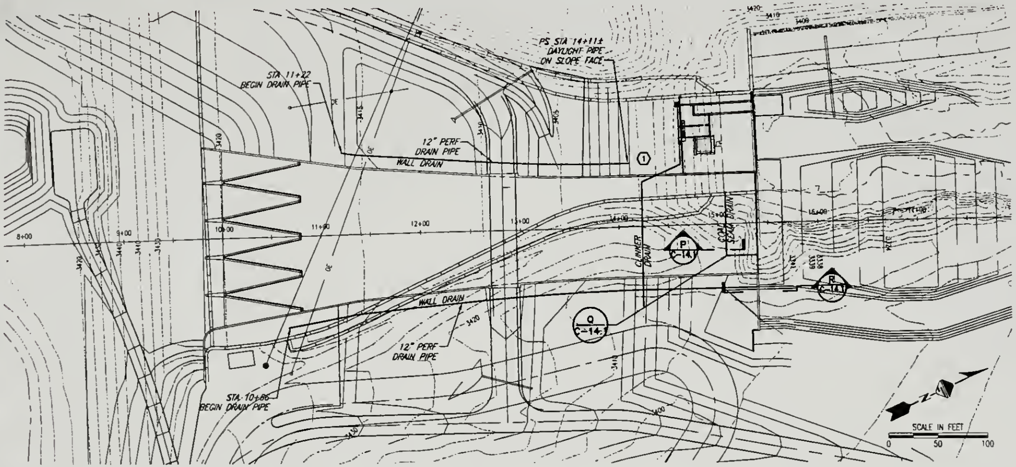
APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

MARY SPILLWAY DRAINAGE SYSTEM
PLAN, SECTIONS AND DETAILS

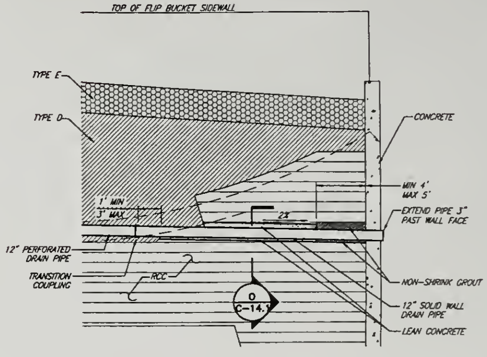
J41

SHEET
C-14.1



PLAN

① PS STA 14+08 TO 14+13± INSTALL SOLID WALL DRAIN PIPE. EXTEND END OF PIPE TWO FEET BEYOND FACE OF SLOPE. SECURE 1/2" MESH SS HARDWARE CLOTH TO END OF PIPE WITH SS BAND.

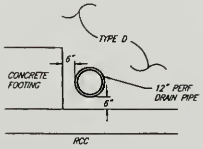


R
C-14.1

SECTION
WALL DRAIN DISCHARGE PIPE

SCALE: 1" = 5'

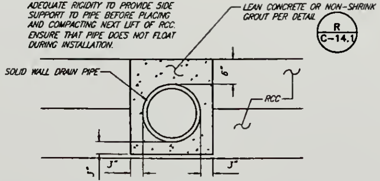
NOTE:
CONCRETE TO HAVE "INITIAL SET" AND ADEQUATE RIGIDITY TO PROVIDE SIDE SUPPORT TO PIPE BEFORE PLACING AND COMPACTING NEXT LIFT OF RCC. ENSURE THAT PIPE DOES NOT FLOAT DURING INSTALLATION.



N
C-11

DETAIL
WALL DRAIN

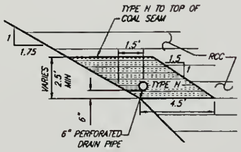
SCALE: 1/2" = 1'



O
C-14.1

TYPICAL SECTION
SOLID WALL DRAIN PIPE
6" COAL SEAM & 12" WALL DRAINS

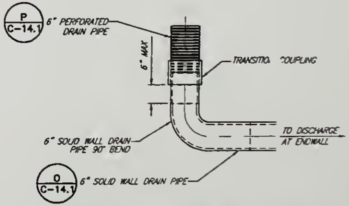
SCALE: 1" = 1'



P
C-14.1

TYPICAL SECTION
COAL SEAM DRAIN

SCALE: 1" = 3'



O
C-14.1

DETAIL
COAL SEAM DRAIN ELBOW

SCALE: 1" = 1'

APPROVED FOR
CONSTRUCTION

NO	BY	DATE	REVISION DESCRIPTION

MAX	SM	
DRAWN	DESIGNED	CHECKED
WRK	7/97	141 9501
APPROVED	DATE	PROJECT NO

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

Prepared By:
ESA CONSULTANTS INC.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

PRIMARY SPILLWAY DRAINAGE SYSTEM
PLAN, SECTIONS AND DETAILS

J41

SHEET
C-14 1

NOTES:

- THE SYMBOL ① & ② DENOTE RELATIVE PLACING SEQUENCE OF CONCRETE POURS. THERE SHALL BE A MINIMUM OF 5 DAYS BETWEEN ADJACENT POURS.

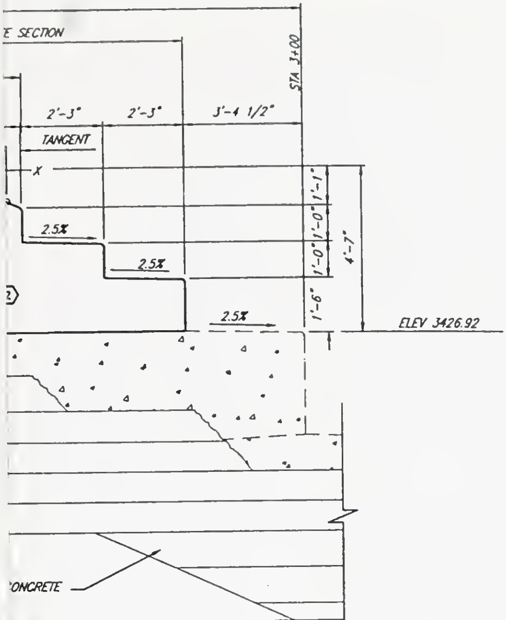
  ① 50% OF THE LONGITUDINAL BARS SHALL BE CONTINUOUS THROUGH THE CONSTRUCTION JOINTS. SPLICE LENGTH OF DOWEL BARS SHALL BE 27". THE JOINT BETWEEN THE SIDEWALL SHALL NOT HAVE REINFORCEMENT THROUGH THE JOINT AND THE CONTACT SURFACE SHALL BE COATED WITH DEBONDING AGENT.

- SURFACE OF OGEE SECTION SHALL HAVE CLASS F4 AND U3 FINISH.

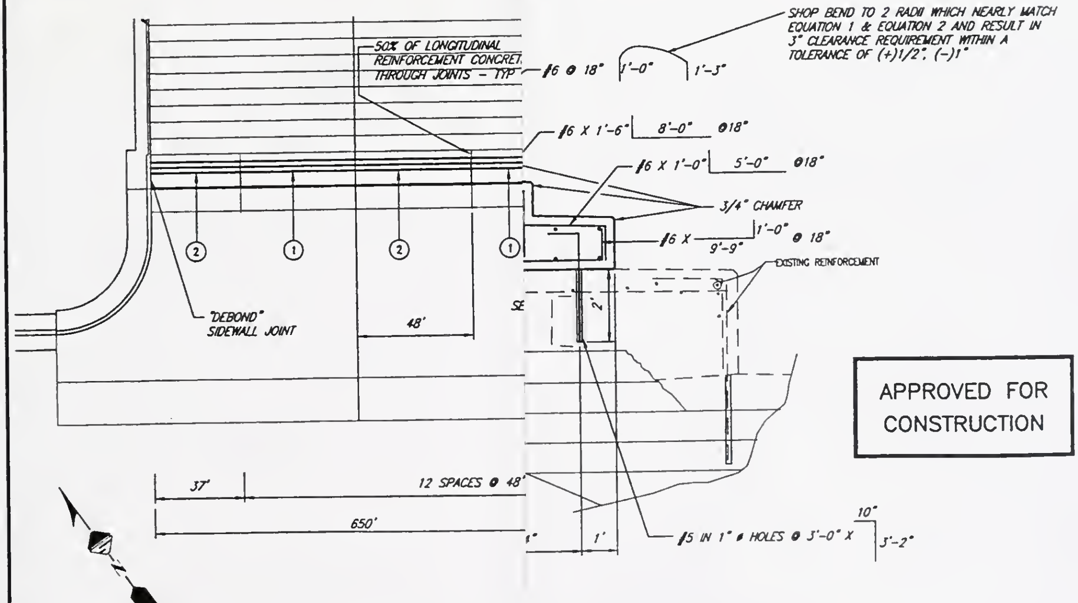
  ② THE CONTACT SURFACES BETWEEN THE OGEE BASE AND OGEE SECTION SHALL BE CLEANED BY SANDBLASTING PRIOR TO PLACING THE CONCRETE IN THE OGEE SECTION.

- CURING; THE OGEE SECTION CONCRETE SHALL BE CURED BY "WET CURING."

  ③ PLACE BRASS MONUMENT CAP, PROVIDED BY OWNER, PER DIRECTION OF ENGINEER.



CTION
SPILLWAY OGEE
/2" = 1'-0"


SHOP BEND TO 2 RADII WHICH NEARLY MATCH EQUATION 1 & EQUATION 2 AND RESULT IN 3" CLEARANCE REQUIREMENT WITHIN A TOLERANCE OF (+)1/2", (-)1"
50% OF LONGITUDINAL REINFORCEMENT CONCRET THROUGH JOINTS - TYP
#6 @ 18"
1'-0"
1'-3"
#6 X 1'-6"
8'-0"
@18"
#6 X 1'-0"
5'-0"
@18"
3/4" CHAMFER
#6 X
1'-0"
9'-9"
@ 18"
EXISTING REINFORCEMENT
②
①
②
①
"DEBOND" SIDEWALL JOINT
48'
SE
2'
37'
12 SPACES @ 48'
650'
1'
#5 IN 1" # HOLES @ 3'-0" X
10"
3'-2"
N

APPROVED FOR CONSTRUCTION

HALF PLAN OF EE

SCALE IN FEET
0 30 60

NO	BY	DATE	REVISION DESCRIPTION

MERGENCY SPILLWAY OGEE CREST
PLAN AND SECTIONS

J43

SHEET
S-92

NOTES:
- THE SYMBOL ① & ② DENOTE RELATIVE PLACING SEQUENCE OF CONCRETE POURS. THERE SHALL BE A MINIMUM OF 5 DAYS BETWEEN ADJACENT POURS.

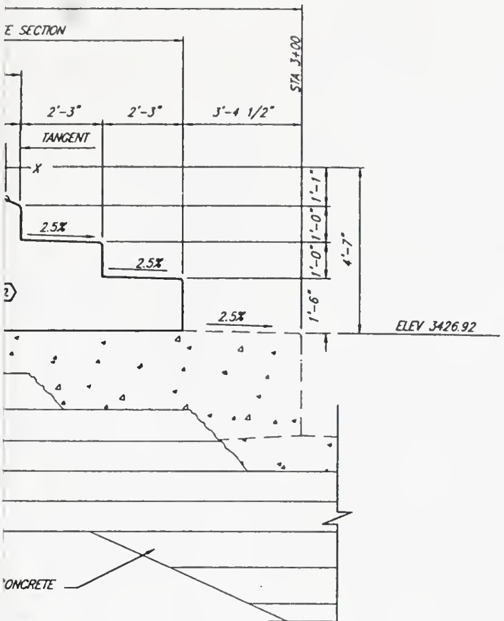
  ① 50% OF THE LONGITUDINAL BARS SHALL BE CONTINUOUS THROUGH THE CONSTRUCTION JOINTS. SPLICE LENGTH OF DOWEL BARS SHALL BE 27". THE JOINT BETWEEN THE SIDEWALL SHALL NOT HAVE REINFORCEMENT THROUGH THE JOINT AND THE CONTACT SURFACE SHALL BE COATED WITH DEBONDING AGENT.

- SURFACE OF OGEE SECTION SHALL HAVE CLASS F4 AND U3 FINISH.

  ② THE CONTACT SURFACES BETWEEN THE OGEE BASE AND OGEE SECTION SHALL BE CLEANED BY SANDBLASTING PRIOR TO PLACING THE CONCRETE IN THE OGEE SECTION.

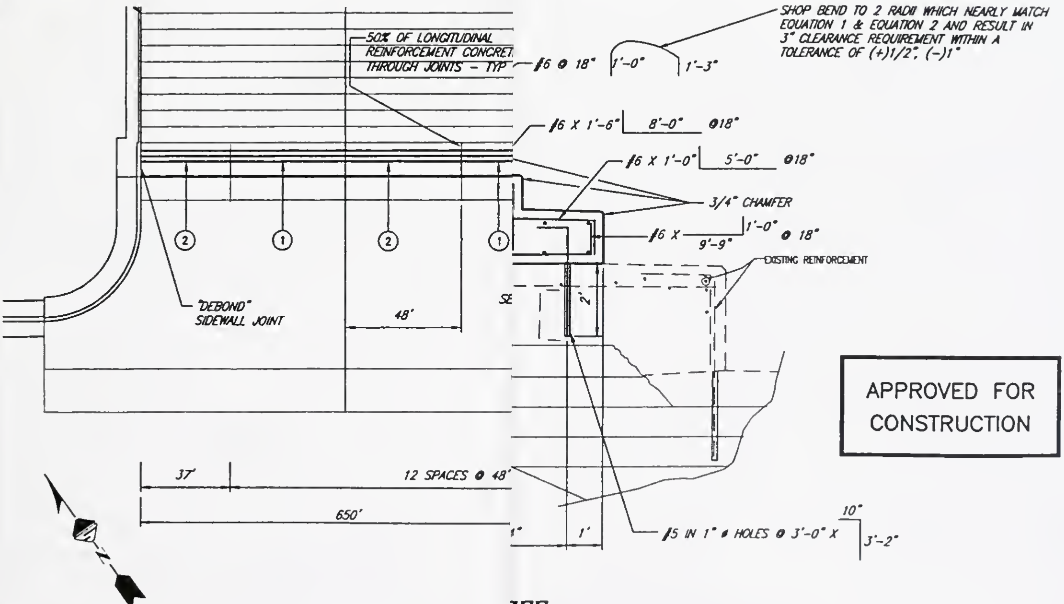
- CURING; THE OGEE SECTION CONCRETE SHALL BE CURED BY "WET CURING."

  ③ PLACE BRASS MONUMENT CAP, PROVIDED BY OWNER, PER DIRECTION OF ENGINEER.



CTION
SPILLWAY OGEE

/2" = 1'-0"


50% OF LONGITUDINAL REINFORCEMENT CONCRET THROUGH JOINTS – TYP
#6 @ 18"
1'-0"
1'-3"
SHOP BEND TO 2 RADII WHICH NEARLY MATCH EQUATION 1 & EQUATION 2 AND RESULT IN 3" CLEARANCE REQUIREMENT WITHIN A TOLERANCE OF (+)1/2", (-)1"
#6 X 1'-6"
8'-0"
@18"
#6 X 1'-0"
5'-0"
@18"
3/4" CHAMFER
#6 X
9'-9"
1'-0"
@ 18"
EXISTING REINFORCEMENT
②
①
②
①
"DEBOND" SIDEWALL JOINT
48'
SE
2'
37'
12 SPACES @ 48'
650'
1"
1'
#5 IN 1" ø HOLES @ 3'-0" X
10"
3'-2"
N

APPROVED FOR CONSTRUCTION

HALF PLAN OF EE

SCALE IN FEET
0 30 60

DWG TM51F052

NO	BY	DATE	REVISION DESCRIPTION

MERGENCY SPILLWAY OGEE CREST
PLAN AND SECTIONS

J43

SHEET
S-92

NOTES:

- THE SYMBOL ① & ② DENOTE RELATIVE PLACING SEQUENCE OF CONCRETE POURS. THERE SHALL BE A MINIMUM OF 5 DAYS BETWEEN ADJACENT POURS.

  ① 50% OF THE LONGITUDINAL BARS SHALL BE CONTINUOUS THROUGH THE CONSTRUCTION JOINTS. SPLICE LENGTH OF DOWEL BARS SHALL BE 27". THE JOINT BETWEEN THE SIDEWALL SHALL NOT HAVE REINFORCEMENT THROUGH THE JOINT AND THE CONTACT SURFACE SHALL BE COATED WITH DEBONDING AGENT.

- SURFACE OF OGEE SECTION SHALL HAVE CLASS F4 AND U3 FINISH.

  ② THE CONTACT SURFACES BETWEEN THE OGEE BASE AND OGEE SECTION SHALL BE CLEANED BY SANDBLASTING PRIOR TO PLACING THE CONCRETE IN THE OGEE SECTION.

- CURING; THE OGEE SECTION CONCRETE SHALL BE CURED BY "WET CURING."

  ③ PLACE BRASS MONUMENT CAP, PROVIDED BY OWNER, PER DIRECTION OF ENGINEER.

OGEE SURFACE COORDINATES

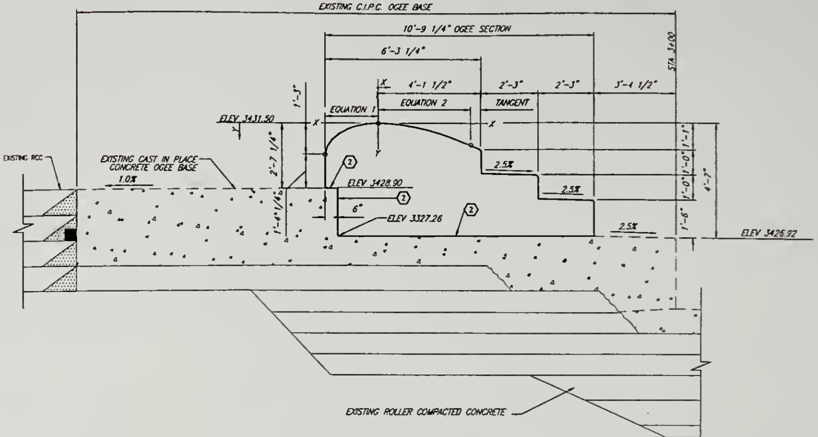
EQUATION 1:

$$Y = 1.256 - \left[1.577737 - \frac{X^2}{2.914859}\right]^{1/2}$$

X	Y	ELEV
-2.15	1.256	3429.35
-2.00	0.803	
-1.75	0.530	
-1.50	0.358	
-1.25	0.235	
-1.00	0.145	
-0.75	0.080	
-0.50	0.035	
-0.25	0.009	
0.00	0.000	3431.50

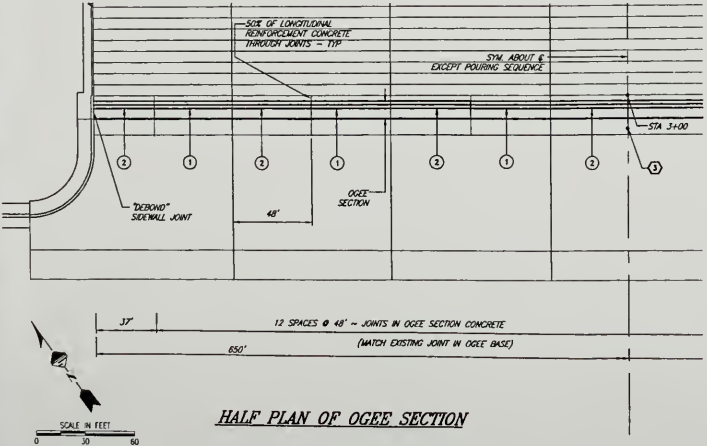
EQUATION 2: $Y = \left(\frac{1}{12.70}\right)\left(X^{1.85}\right)$

	X	Y	ELEV
EQUATION 2	0	0	3431.50
	0.5	.022	
	1.00	.079	
	1.50	.167	
	2.00	.284	
	2.50	.429	
	3.00	.601	
	3.50	.797	
	3.72	.895	
TANGENT	4.13	1.077	
	6.38	2.077	
	8.63	3.077	

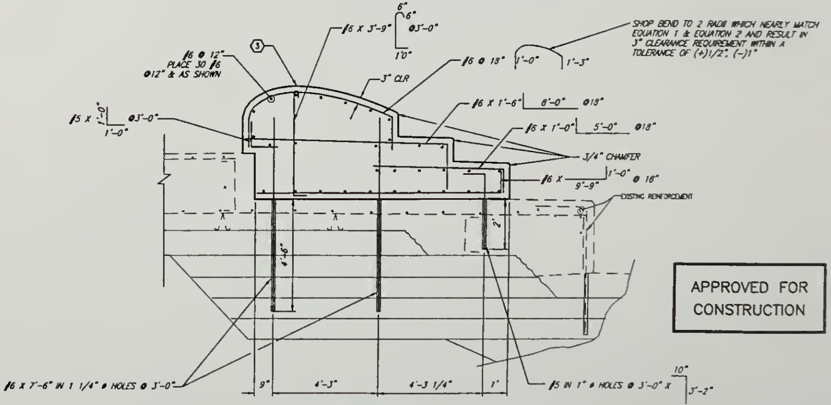


SECTION
EMERGENCY SPILLWAY OGEE

SCALE: 1/2" = 1'-0"


50% OF LONGITUDINAL REINFORCEMENT CONCRETE THROUGH JOINTS – TYP
SYM. ABOUT ℄ EXCEPT POURING SEQUENCE
STA 3+00
2
1
2
1
2
1
2
3
"DEBOND" SIDEWALL JOINT
48'
OGEE SECTION
37'
12 SPACES @ 48' ~ JOINTS IN OGEE SECTION CONCRETE
(MATCH EXISTING JOINT IN OGEE BASE)
650'
SCALE IN FEET
0
30
60

HALF PLAN OF OGEE SECTION


6"
6"
#6 X 3'-9"
@3'-0"
1'0"
SHOP BEND TO 2 RADII WHICH NEARLY MATCH EQUATION 1 & EQUATION 2 AND RESULT IN 3" CLEARANCE REQUIREMENT WITHIN A TOLERANCE OF (+)1/2", (-)1"
3
#6 @ 12" PLACE 30 #6 @12" & AS SHOWN
#6 @ 18"
1'-0"
1'-3"
3" CLR
#5 X 1'-0"
@3'-0"
1'-0"
#6 X 1'-6"
8'-0"
@18"
#6 X 1'-0"
5'-0"
@18"
3/4" CHAMFER
#6 X
1'-0"
9'-9"
@ 18"
EXISTING REINFORCEMENT
2"
4'-6"
#6 X 7'-6" IN 1 1/4" ø HOLES @ 3'-0"
9"
4'-3"
4'-3 1/4"
1'
#5 IN 1" ø HOLES @ 3'-0" X
10"
3'-2"

APPROVED FOR CONSTRUCTION

SECTION
EMERGENCY SPILLWAY OGEE
REBAR PLACEMENT

SCALE: 1/2" = 1'-0"

NO	BY	DATE	REVISION DESCRIPTION	BMG DRAWN	GFE DESIGNED	CHECKED	
				WRK APPROVED	7/97 DATE	141.9501 PROJECT NO	

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
PRIMARY SPILLWAY & OUTLET WORKS

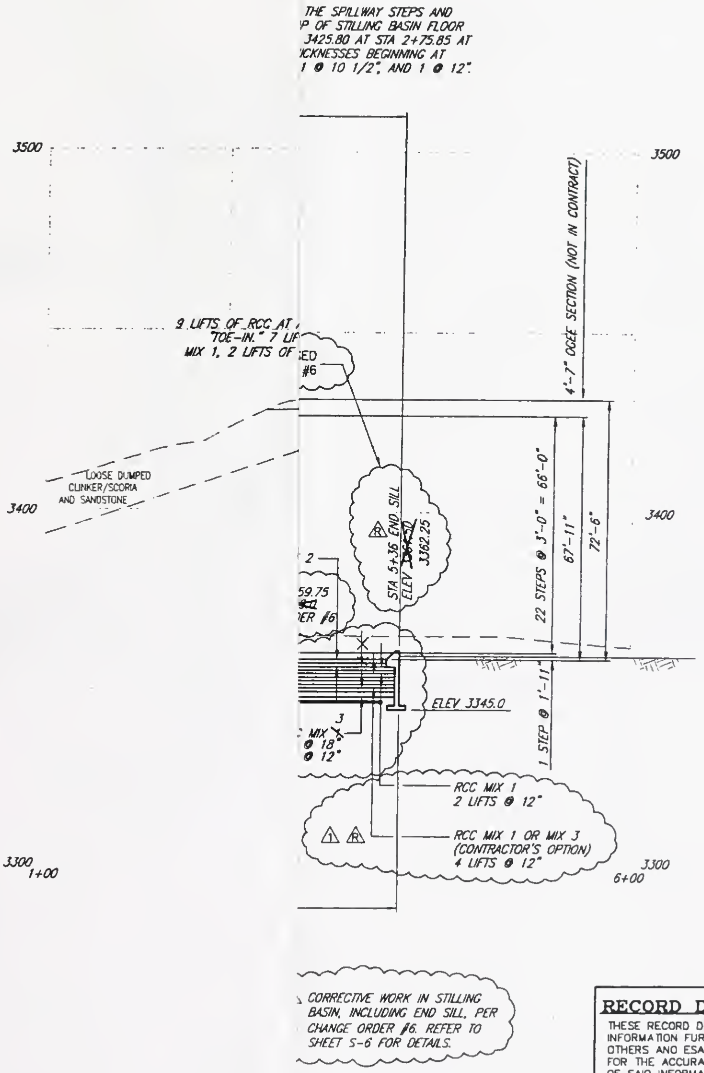
Prepared By:
ESA CONSULTANTS INC.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

EMERGENCY SPILLWAY OGEE CREST
PLAN AND SECTIONS

J43

SHEET
S-92

DOUGLAS M.
08788



RECORD DRAWINGS

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ISSUED: SEPTEMBER 1999

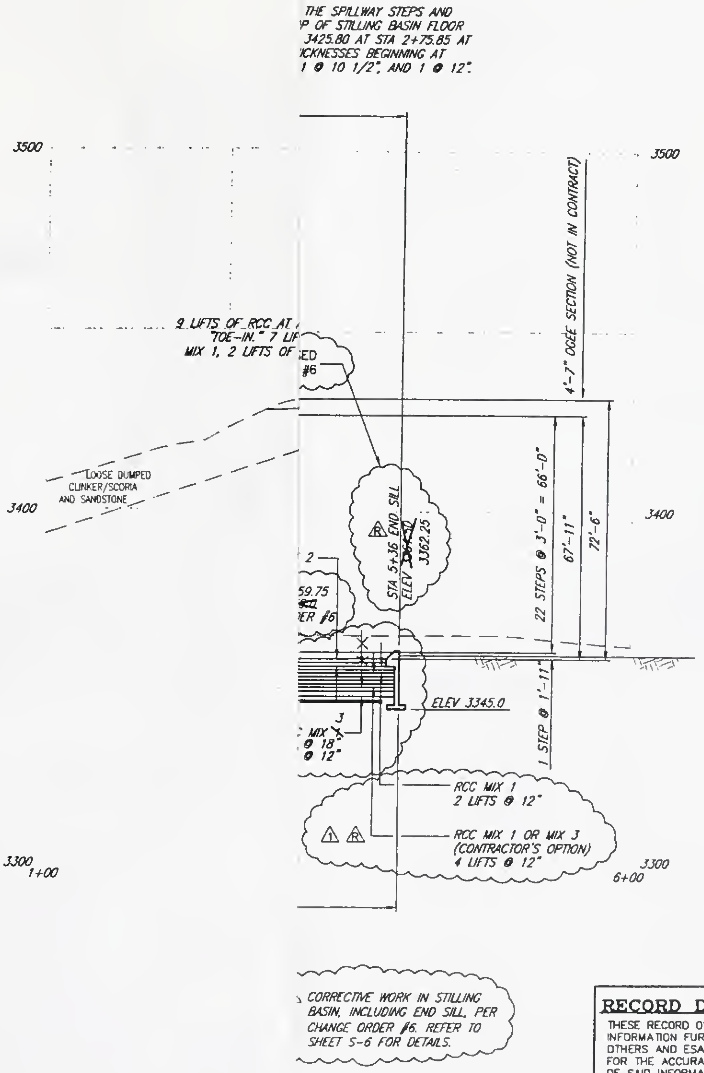
NO.	BY	DATE	REVISION DESCRIPTION
R	TBK	9/14/99	RECORD DRAWING REVISION
1	MAK	2/97	PER ADDENDUM 1

STRUCTURAL
CENTERLINE SECTION

J45

SHEET
S-2

08788



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ISSUED: SEPTEMBER 1999

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1	MAK	2/97	PER ADDENDUM 1

STRUCTURAL
CENTERLINE SECTION

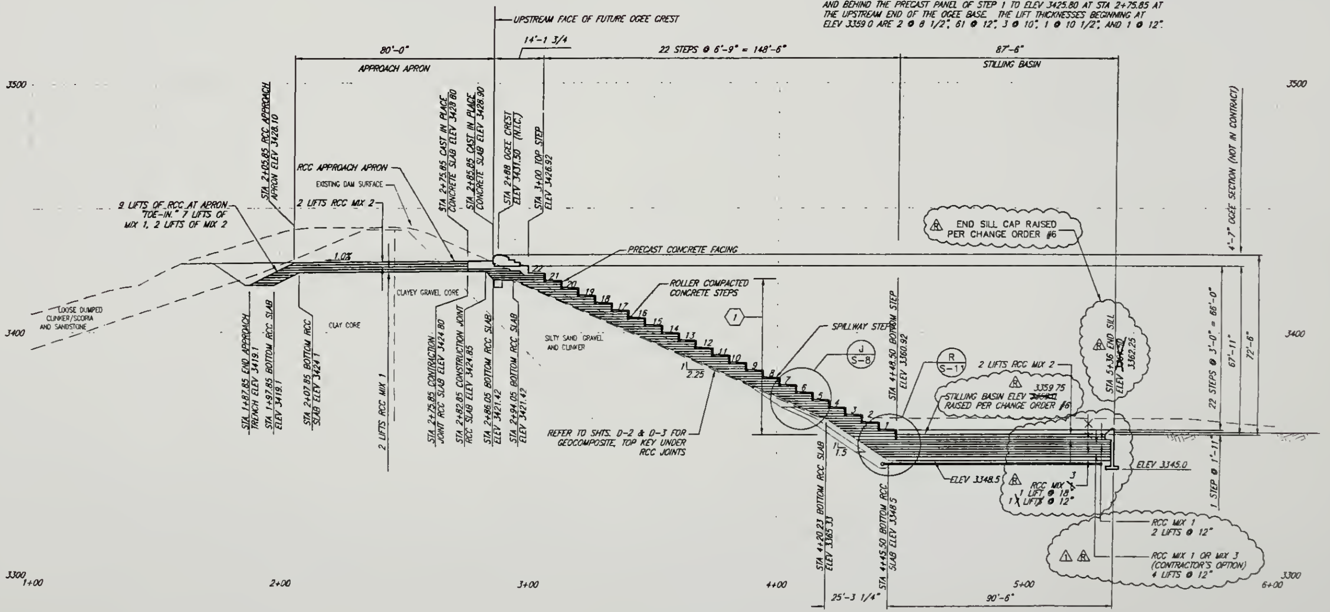
J45

SHEET
S-2

DOUGLAS ... 8788 ... REGISTERED PROFESSIONAL ENGINEER MONTANA

Douglas M. Gibson

(1) RCC MIX 1 SHALL BE USED IN THE CONSTRUCTION OF THE SPILLWAY STEPS AND SHALL EXTEND FROM ELEV 3359.0/STA 4+48.04 AT TOP OF STILLING BASIN FLOOR AND BEHIND THE PRECAST PANEL OF STEP 1 TO ELEV 3425.80 AT STA 2+75.85 AT THE UPSTREAM END OF THE OGEE BASE. THE LIFT THICKNESSES BEGINNING AT ELEV 3359.0 ARE 2 @ 8 1/2", 61 @ 12", 3 @ 10", 1 @ 10 1/2", AND 1 @ 12".



UPSTREAM FACE OF FUTURE OGEE CREST
80'-0"
APPROACH APRON
14'-1 3/4
22 STEPS @ 6'-9" = 148'-6"
87'-6"
STILLING BASIN
3500
3400
3300
STA 2+05.85 RCC APPROACH APRON ELEV 3428.10
RCC APPROACH APRON
EXISTING DAM SURFACE
2 LIFTS RCC MIX 2
9 LIFTS OF RCC AT APRON "TOE-IN." 7 LIFTS OF MIX 1, 2 LIFTS OF MIX 2
1.0%
STA 2+75.85 CAST IN PLACE CONCRETE SLAB ELEV 3428.80
STA 2+85.85 CAST IN PLACE CONCRETE SLAB ELEV 3428.90
STA 2+88 OGEE CREST ELEV 3431.50 (N.I.C.)
STA 3+00 TOP STEP ELEV 3428.92
PRECAST CONCRETE FACING
ROLLER COMPACTED CONCRETE STEPS
CLAYEY GRAVEL CORE
CLAY CORE
SILTY SAND GRAVEL AND CLINKER
LOOSE DUMPED CLINKER/SCORIA AND SANDSTONE
STA 1+87.85 END APPROACH TRENCH ELEV 3419.1
STA 1+97.85 BOTTOM RCC SLAB ELEV 3419.1
STA 2+07.85 BOTTOM RCC SLAB ELEV 3424.1
2 LIFTS RCC MIX 1
STA 2+75.85 CONTRACTION JOINT RCC SLAB ELEV 3424.80
STA 2+82.85 CONSTRUCTION JOINT RCC SLAB ELEV 3424.85
STA 2+86.05 BOTTOM RCC SLAB ELEV 3421.42
STA 2+94.05 BOTTOM RCC SLAB ELEV 3421.42
22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1
2.25
1
1.5
REFER TO SHTS. D-2 & D-3 FOR GEOCOMPOSITE, TOP KEY UNDER RCC JOINTS
SPILLWAY STEP
J S-8
R S-1
STA 4+48.50 BOTTOM STEP ELEV 3360.92
2 LIFTS RCC MIX 2
STILLING BASIN ELEV ~~3359.0~~ 3359.75 RAISED PER CHANGE ORDER #6
END SILL CAP RAISED PER CHANGE ORDER #6
STA 5+36 END SILL ELEV ~~3362.0~~ 3362.25
4'-7" OGEE SECTION (NOT IN CONTRACT)
22 STEPS @ 3'-0" = 66'-0"
67'-11"
72'-6"
1 STEP @ 1'-11"
ELEV 3345.0
ELEV 3348.5
RCC MIX 3 1 LIFT @ 18" 1 LIFT @ 12"
RCC MIX 1 2 LIFTS @ 12"
RCC MIX 1 OR MIX 3 (CONTRACTOR'S OPTION) 4 LIFTS @ 12"
STA 4+20.23 BOTTOM RCC SLAB ELEV 3365.33
STA 4+45.50 BOTTOM RCC SLAB ELEV 3348.5
1+00
2+00
3+00
4+00
5+00
6+00
25'-3 1/4"
90'-6"

CENTERLINE SECTION

A S-1

SCALE: 1" = 20'

CORRECTIVE WORK IN STILLING BASIN, INCLUDING END SILL, PER CHANGE ORDER #6. REFER TO SHEET S-6 FOR DETAILS.

RECORD DRAWINGS

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ISSUED: SEPTEMBER 1999

NO	BY	DATE	REVISION DESCRIPTION
2	TBK	9/14/99	RECORD DRAWING REVISION
1	MAK	2/97	PER ADDENDUM 1

DRAWN	DESIGNED	CHECKED
MAK	WRK	PAS
APPROVED	**DATE**	**PROJECT NO.**
GFE	12/96	141.9501

SCALE HORIZ: 1" = 20' VERT: 1" = 20'

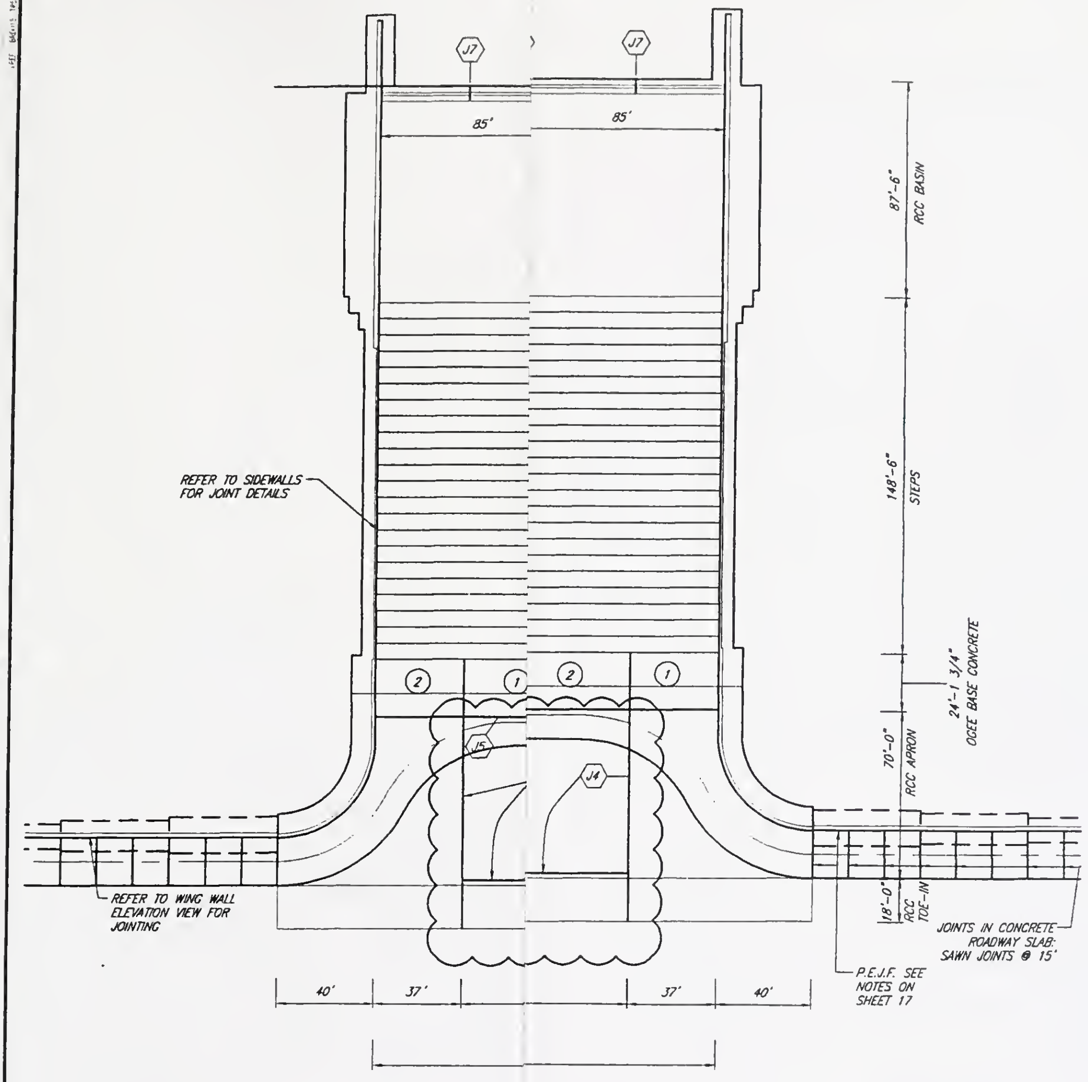
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
216 East Mendenhall, Suite C-1, Bozeman MT 59715

STRUCTURAL
CENTERLINE SECTION

J45

SHEET S-2


J7
J7
85'
85'
87'-6"
RCC BASIN
148'-6"
STEPS
24'-1 3/4"
OGEE BASE CONCRETE
70'-0"
RCC APRON
18'-0"
RCC TOE-IN
REFER TO SIDEWALLS FOR JOINT DETAILS
2
1
2
1
J5
J4
REFER TO WING WALL ELEVATION VIEW FOR JOINTING
JOINTS IN CONCRETE ROADWAY SLAB: SAWN JOINTS @ 15'
P.E.J.F. SEE NOTES ON SHEET 17
40'
37'
37'
40'

T SEQUENCE
CONTRACT

OUT

EET S-20

RECORD DRAWINGS

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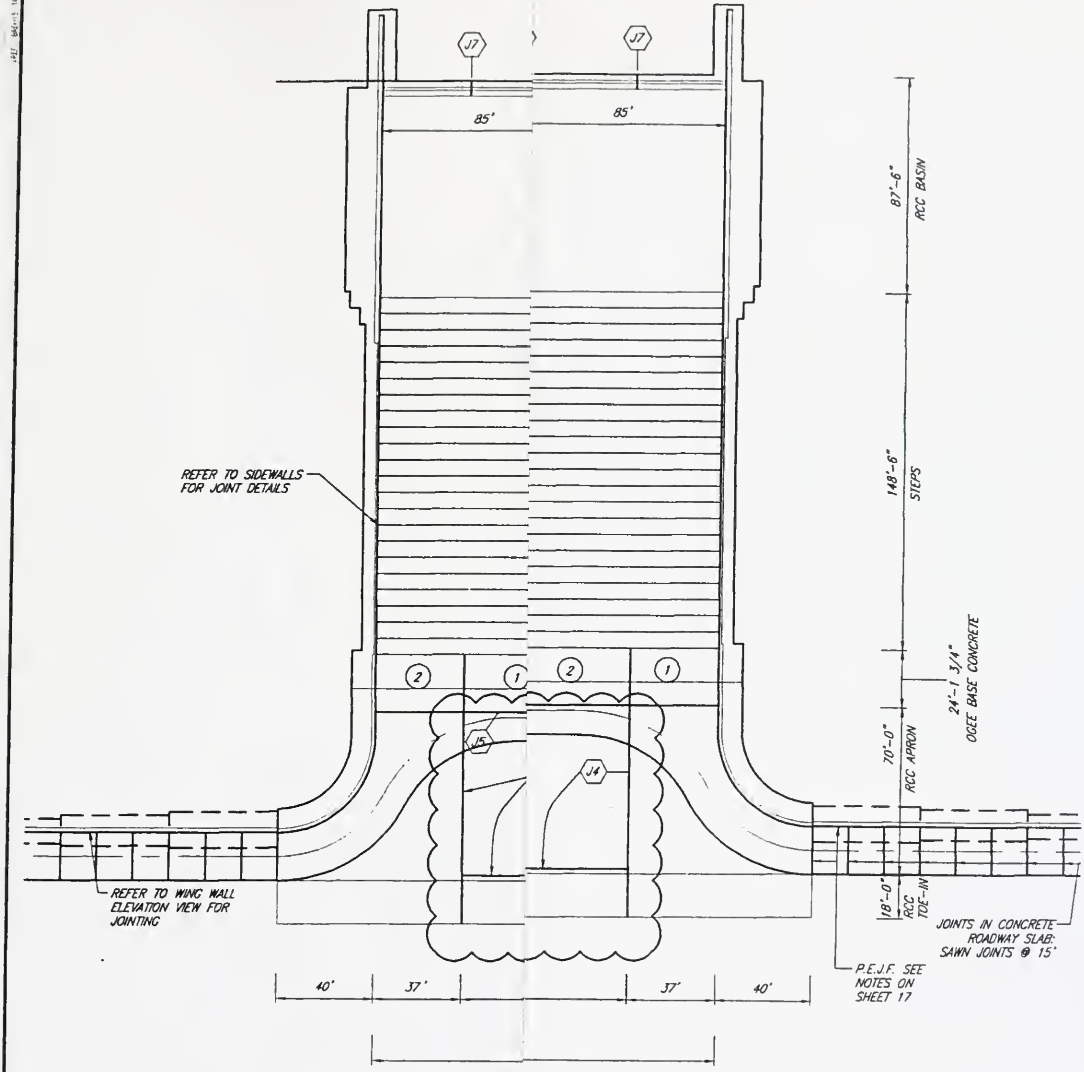
ISSUED: SEPTEMBER 1999

△1	MAK	JAN '97	PER ADDENDUM 3
NO.	BY	DATE	REVISION DESCRIPTION

STRUCTURAL
JOINTING PLAN

J47

SHEET
S-5



T SEQUENCE
CONTRACT

OUT

EET S-20

RECORD DRAWINGS

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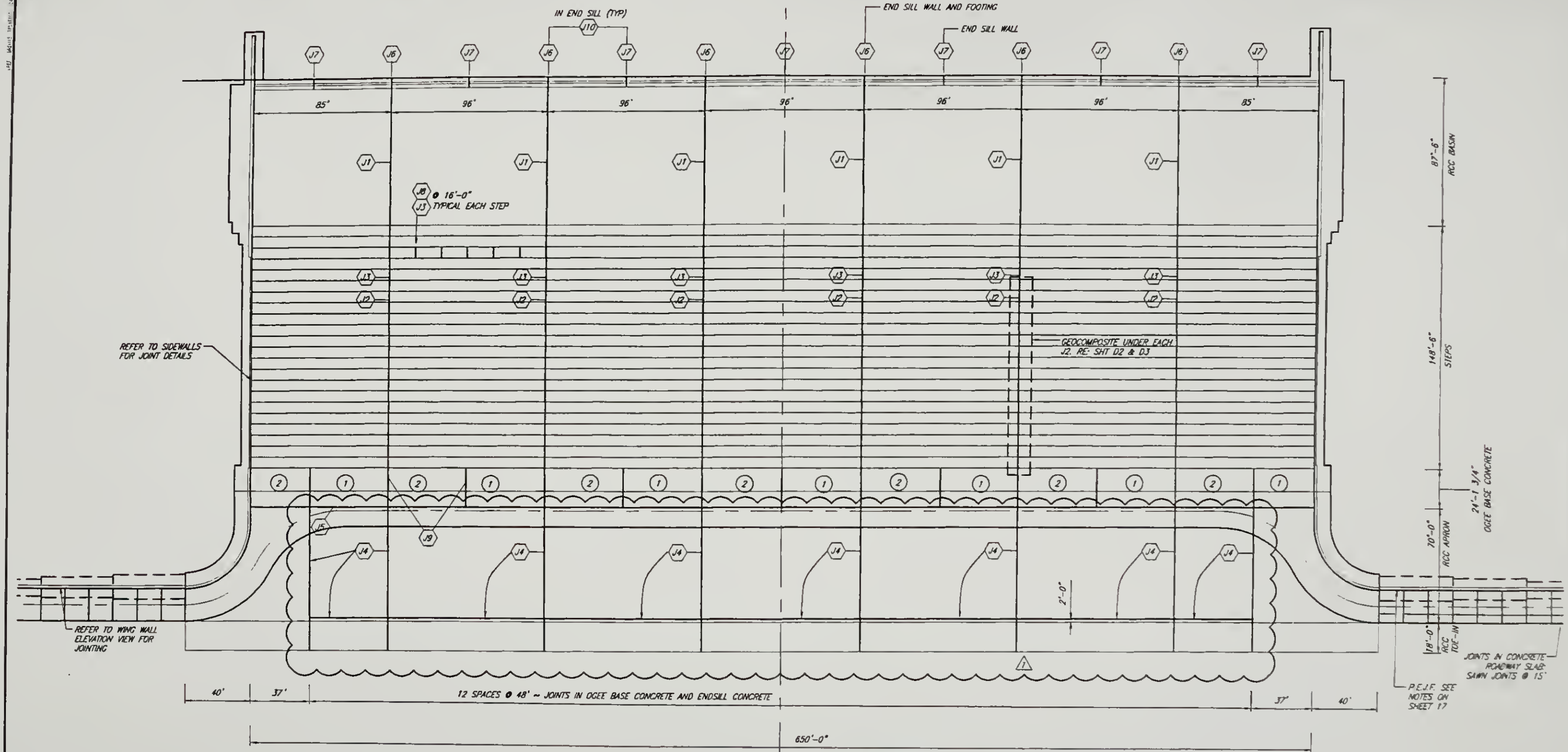
ISSUED: SEPTEMBER 1999

NO.	BY	DATE	REVISION DESCRIPTION
△1	MAK	JAN '97	PER ADDENDUM 3

STRUCTURAL
JOINTING PLAN

J47

SHEET
S-5


IN END SILL (TYP)
J10
END SILL WALL AND FOOTING
END SILL WALL
J7
J6
85'
96'
96'
96'
96'
96'
85'
J1
J8 @ 16'-0"
J3 TYPICAL EACH STEP
J3
J2
GEOCOMPOSITE UNDER EACH J2. RE: SHT D2 & D3
REFER TO SIDEWALLS FOR JOINT DETAILS
87'-6"
RCC BASIN
148'-6"
STEPS
24'-1 3/4"
OGEE BASE CONCRETE
70'-0"
RCC APRON
18'-0"
RCC TOE-IN
1
2
J5
J9
J4
2'-0"
REFER TO WING WALL ELEVATION VIEW FOR JOINTING
JOINTS IN CONCRETE ROADWAY SLAB: SAWN JOINTS @ 15'
P.E.J.F. SEE NOTES ON SHEET 17
40'
37'
12 SPACES @ 48' ~ JOINTS IN OGEE BASE CONCRETE AND ENDSILL CONCRETE
37'
40'
650'-0"

NOTES

(1) OGEE BASE PLACEMENT SEQUENCE
OGEE SECTION NOT IN CONTRACT

(J1) JOINTING DETAIL CALLOUT

SEE JOINTING SCHEDULE ON SHEET S-20

RECORD DRAWINGS

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ISSUED: SEPTEMBER 1999

NO	BY	DATE	REVISION DESCRIPTION
1	MAK	JAN '97	PER ADDENDUM 3

BMG/MAK DRAWN	CFE DESIGNED	PAS CHECKED
CFE APPROVED	12/98 DATE	141.9501 PROJECT NO.

SCALE
HORIZ. 1"=30' VERT N/A

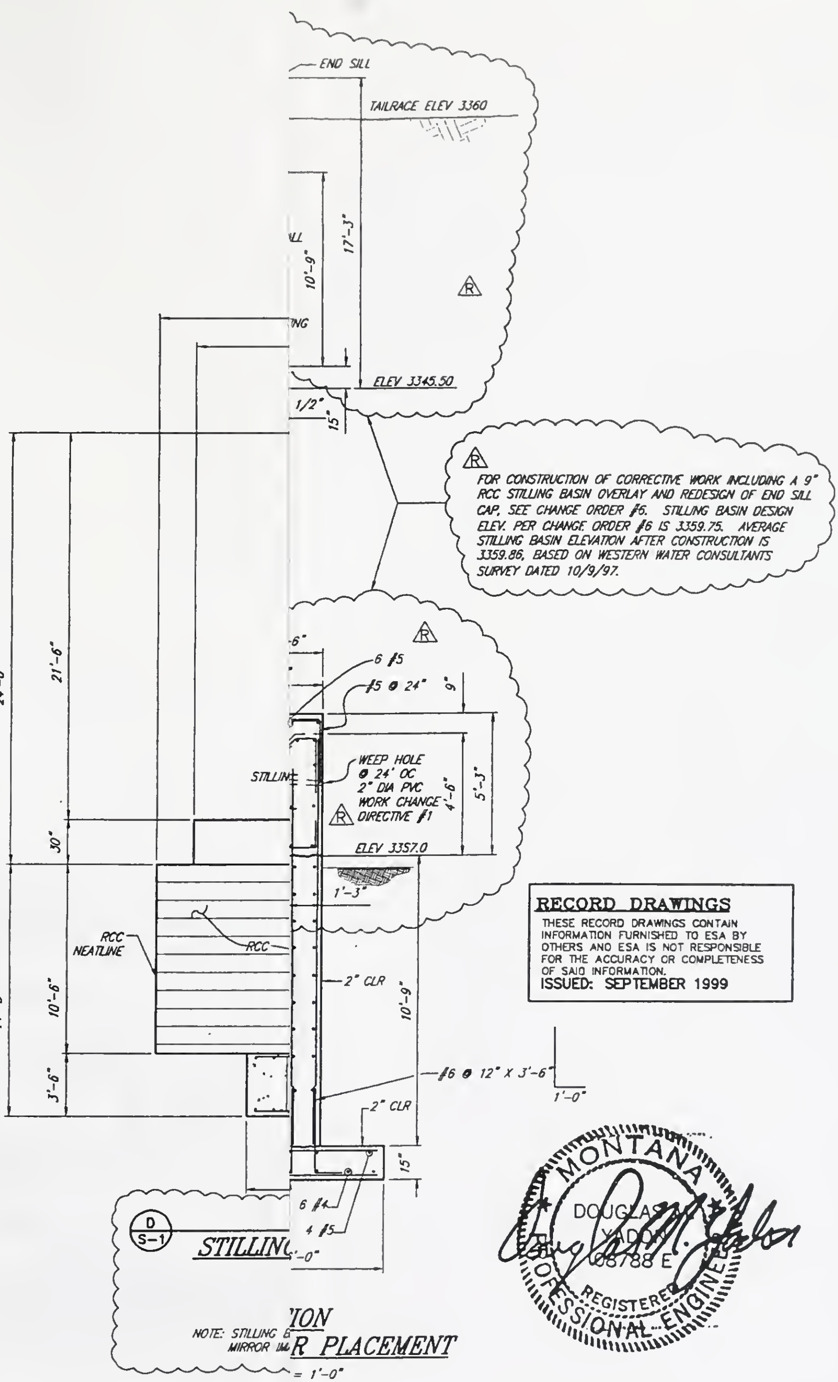
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
315 West Mendenhall, Suite C-1, Bozeman MT. 59715

STRUCTURAL
JOINTING PLAN

J47

SHEET
S-5



FOR CONSTRUCTION OF CORRECTIVE WORK INCLUDING A 9" RCC STILLING BASIN OVERLAY AND REDESIGN OF END SILL CAP, SEE CHANGE ORDER #6. STILLING BASIN DESIGN ELEV. PER CHANGE ORDER #6 IS 3359.75. AVERAGE STILLING BASIN ELEVATION AFTER CONSTRUCTION IS 3359.86, BASED ON WESTERN WATER CONSULTANTS SURVEY DATED 10/9/97.

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ISSUED: SEPTEMBER 1999

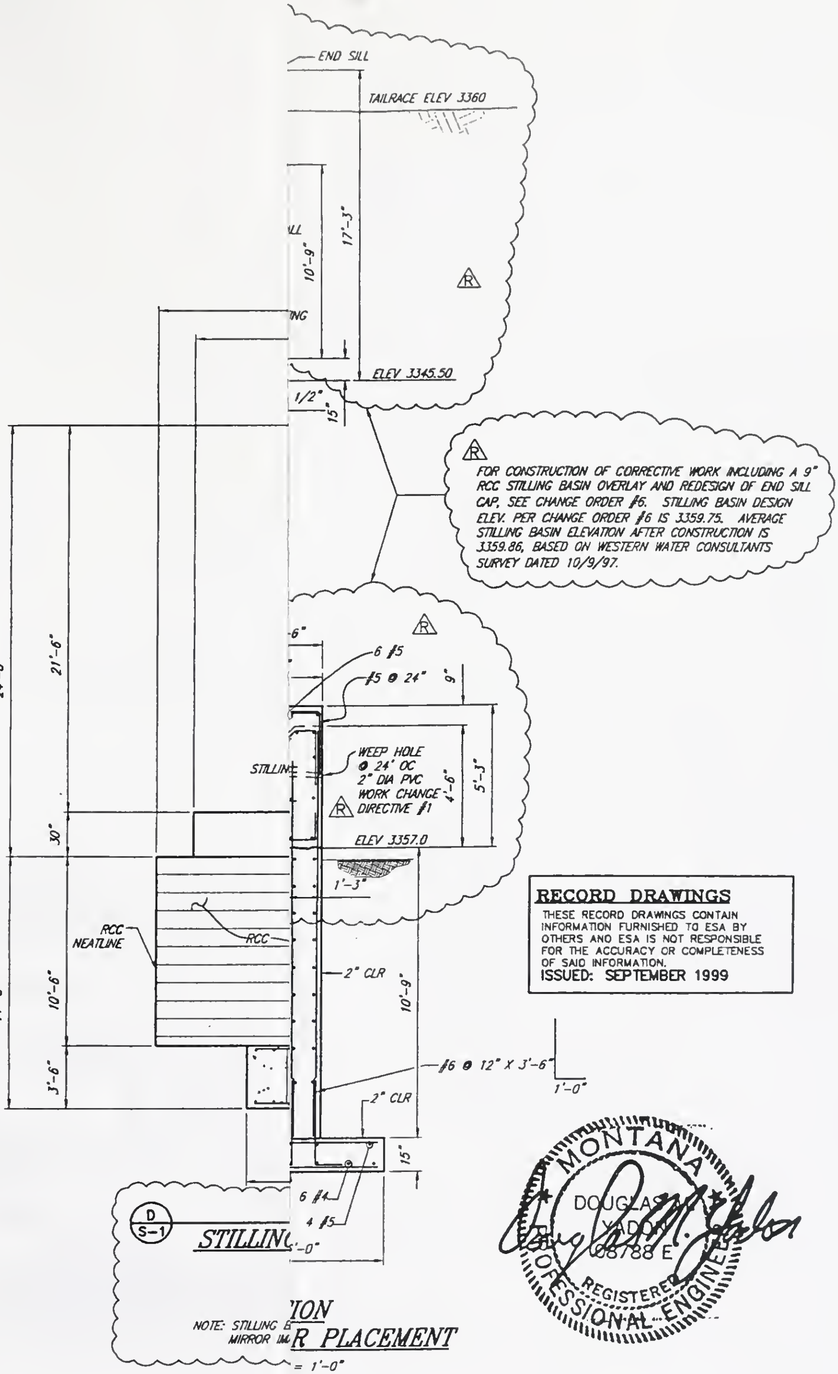
MONTANA
DOUGLAS YADON
08788 E
REGISTERED PROFESSIONAL ENGINEER

NO	BY	DATE	REVISION DESCRIPTION
R	TBK	9/16/99	RECORD DRAWING REVISION
1	MAK	12/97	PER ADDENDUM 1 AND 2

STRUCTURAL
END SILL

J49

SHEET
S-6



R FOR CONSTRUCTION OF CORRECTIVE WORK INCLUDING A 9" RCC STILLING BASIN OVERLAY AND REDESIGN OF END SILL CAP, SEE CHANGE ORDER #6. STILLING BASIN DESIGN ELEV. PER CHANGE ORDER #6 IS 3359.75. AVERAGE STILLING BASIN ELEVATION AFTER CONSTRUCTION IS 3359.86, BASED ON WESTERN WATER CONSULTANTS SURVEY DATED 10/9/97.

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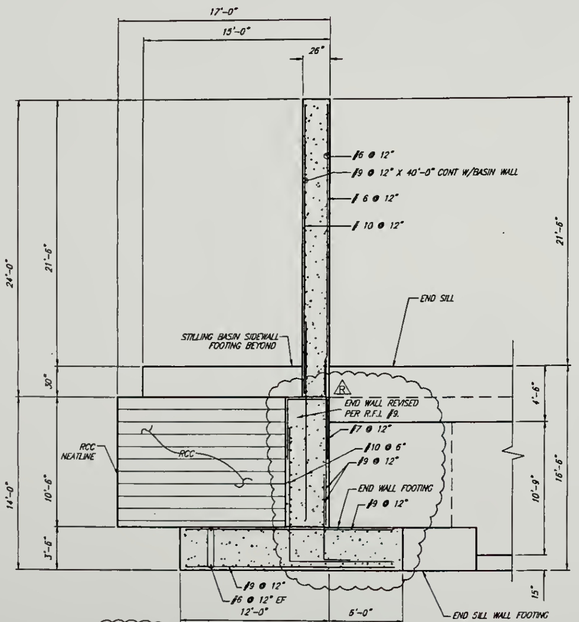
DOUGLAS M. YADON
08788 E

R	TBK	9/16/99	RECORD DRAWING REVISION
1	MAK	12/97	PER ADDENDUM 1 AND 2
NO	BY	DATE	REVISION DESCRIPTION

STRUCTURAL
END SILL

J49

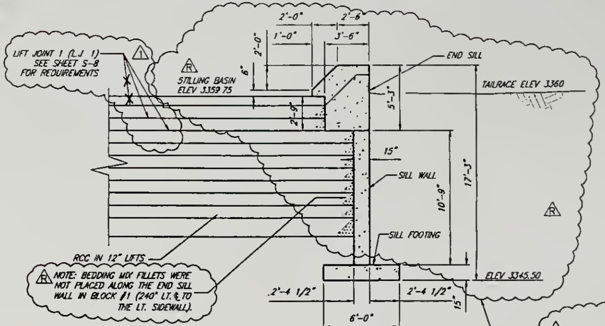
SHEET
S-6



D / S-1 **ELEVATION** ~~LEFT~~ RIGHT
STILLING BASIN SIDEWALL
AT END SILL

SCALE: 1/4" = 1'-0"

NOTE: STILLING BASIN LEFT SIDEWALL IS THE MIRROR IMAGE OF SECTION D/S-1. △1

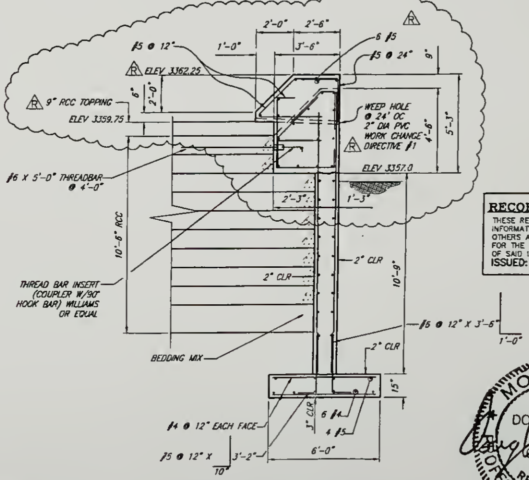


R NOTE: BEDDING MIX FILLETS WERE NOT PLACED ALONG THE END SILL WALL IN BLOCK #1 (240' LT. ℄ TO THE LT. SIDEWALL).

R FOR CONSTRUCTION OF CORRECTIVE WORK INCLUDING A 9" RCC STILLING BASIN OVERLAY AND REDESIGN OF END SILL CAP, SEE CHANGE ORDER #6. STILLING BASIN DESIGN ELEV. PER CHANGE ORDER #6 IS 3359.75. AVERAGE STILLING BASIN ELEVATION AFTER CONSTRUCTION IS 3359.86, BASED ON WESTERN WATER CONSULTANTS SURVEY DATED 10/9/97.

E / S-1 **SECTION**
END SILL

SCALE: 1/4" = 1'-0"



F / S-1 **SECTION**
END SILL REBAR PLACEMENT

SCALE: 3/8" = 1'-0"

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DOUGLAS YADON
08788 E

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1	MAK	12/97	PER ADDENDUM 1 AND 2

BMG/MAK DRAWN	GFE, PAS DESIGNED	PAS CHECKED
GFE APPROVED	12/98 DATE	141.9501 PROJECT NO

SCALE
HORIZ. N/A VERT N/A

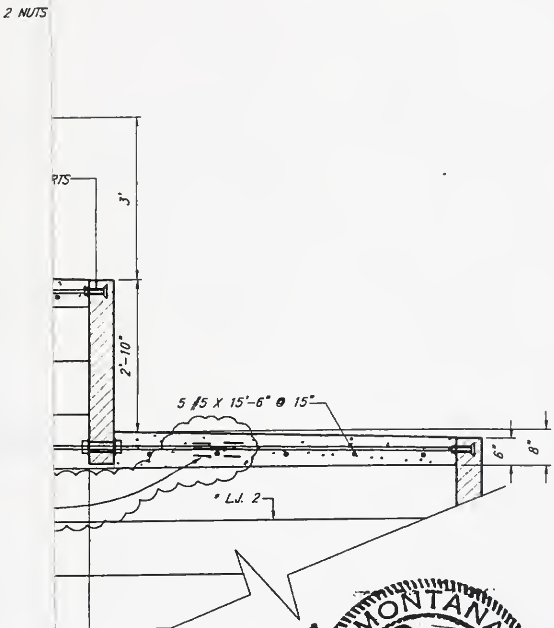
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

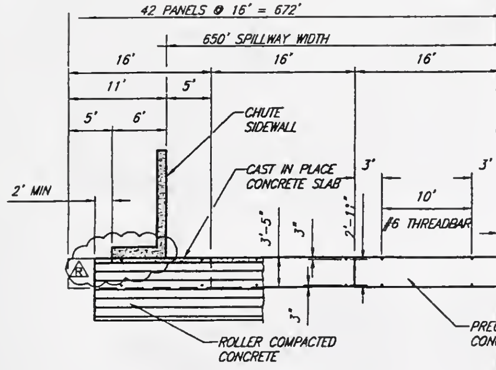
STRUCTURAL
END SILL

J49

SHEET
S-6



MONTANA
DOUGLAS M. YARIAN
08788 E
REGISTERED
PROFESSIONAL ENGINEER



ELEVATION
PRECAST PANELS AT CHUTE SIDE
JOINT LOCATIONS/THREADBAR SPA

SCALE: 1/8" = 1'-0"

LIFT JOINT REQUIREMENTS

JOINT LOCATION	T = TIME BETWEEN LIFTS (HOURS)	M = MATURITY (DEGREE F - HOURS)	JOINT CLASS.	PLAN MARK AND SHEET NO.
Stilling Basin Top Lifts and Apron Lifts	T<4H T<4H T>4H	M<210°H M>210°H ———	Unclass. Type I Type II	L.J. 1 S-6 S-11 S-16
Top Lift at Steps	T<18H T<18H T>18H	M<750°H M>750°H ———	Unclass. Type I Type II	L.J. 2 S-15 S-8
All Other Lift Joints	T<36H T<36H T>36H	M<1500°H M>1500°H ———	Unclass. Type I Type II	———

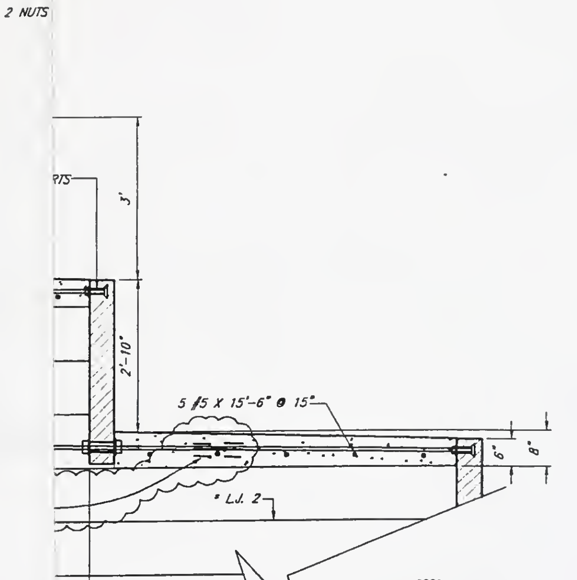
NOTE: COORDINATE WITH ENTIRE RCC SPECIFICATION. JOINTS ARE IN SECTION 3.5 OF 03100.

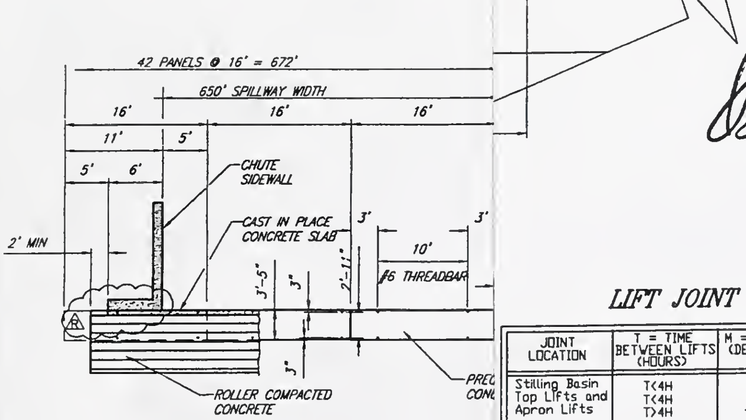
NO	BY	DATE	REVISION DESCRIPTION
R	TBK	9/22/99	RECORD DRAWING REVISION
1	MAK	1/97	PER ADDENDUM 2

STRUCTURAL
STEPS

J51

SHEET
S-8





ELEVATION

PRECAST PANELS AT CHUTE SIDE
JOINT LOCATIONS/THREADBAR SPA

SCALE: 1/8" = 1'-0"

08788 E

LIFT JOINT REQUIREMENTS

JOINT LOCATION	T = TIME BETWEEN LIFTS (HOURS)	M = MATURITY (DEGREE F - HOURS)	JOINT CLASS.	PLAN MARK AND SHEET NO.
Stilling Basin Top Lifts and Apron Lifts	T<4H T<4H T>4H	M<210°H M>210°H ———	Unclass. Type I Type II	L.J. 1 S-6 S-11 S-16
Top Lift at Steps	T<18H T<18H T>18H	M<750°H M>750°H ———	Unclass. Type I Type II	L.J. 2 S-15 S-8
All Other Lift Joints	T<36H T<36H T>36H	M<1500°H M>1500°H ———	Unclass. Type I Type II	———

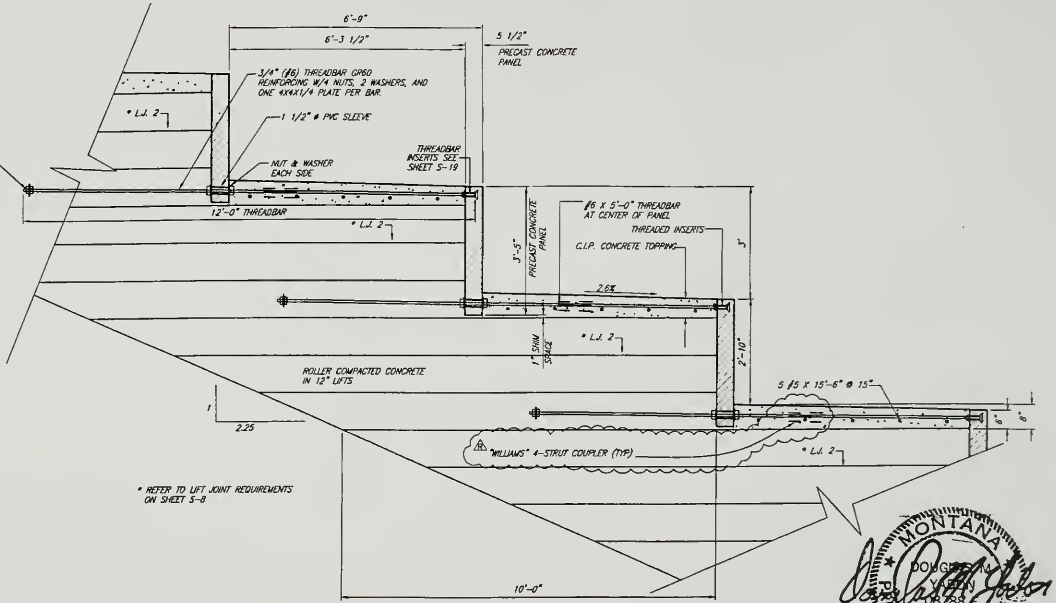
NOTE: COORDINATE WITH ENTIRE RCC SPECIFICATION. JOINTS ARE IN SECTION 3.5 OF 03100.

NO	BY	DATE	REVISION DESCRIPTION
R	TBK	9/22/99	RECORD DRAWING REVISION
1	MAK	1/97	PER ADDENDUM 2

STRUCTURAL
STEPS

J51

SHEET
S-8



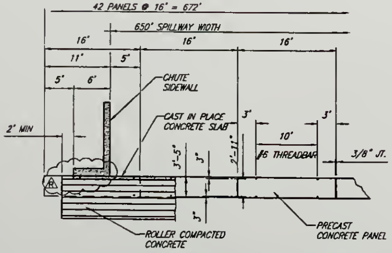
• REFER TO LIFT JOINT REQUIREMENTS ON SHEET S-8

JK S-2

SPILLWAY STEPS SECTION
REBAR AND THREADBAR ANCHORING

SCALE: 3/4" = 1'-0"

DOUGLAS M. YOUNG 08788 E
REGISTERED PROFESSIONAL ENGINEER
MONTANA



ELEVATION
PRECAST PANELS AT CHUTE SIDEWALL
JOINT LOCATIONS/THREADBAR SPACING

SCALE: 1/8" = 1'-0"

LIFT JOINT REQUIREMENTS

JOINT LOCATION	T = TIME BETWEEN LIFTS (HOURS)	M = MATURITY (DEGREE F - HOURS)	JOINT CLASS.	PLAN MARK AND SHEET NO.
Stilling Basin Top Lifts and Apron Lifts	T<4H T<4H T>4H	M<210°H M>210°H ———	Unclass. Type I Type II	L.J. 1 S-6 S-11 S-16
Top Lift at Steps	T<18H T<18H T>18H	M<750°H M>750°H ———	Unclass. Type I Type II	L.J. 2 S-15 S-8
All Other Lift Joints	T<36H T<36H T>36H	M<1500°H M>1500°H ———	Unclass. Type I Type II	———

NOTE. COORDINATE WITH ENTIRE RCC SPECIFICATION. JOINTS ARE IN SECTION 3.5 OF 03100.

RECORD DRAWINGS

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ISSUED: SEPTEMBER 1999

NO	BY	DATE	REVISION DESCRIPTION
△	TBK	9/22/99	RECORD DRAWING REVISION
△	MAK	1/97	PER ADDENDUM 2

MAK DRAWN
GFE, PAS DESIGNED
PAS CHECKED
GFE APPROVED
12/96 DATE
141 9501 PROJECT NO.
SCALE HORIZ. N/A VERT N/A

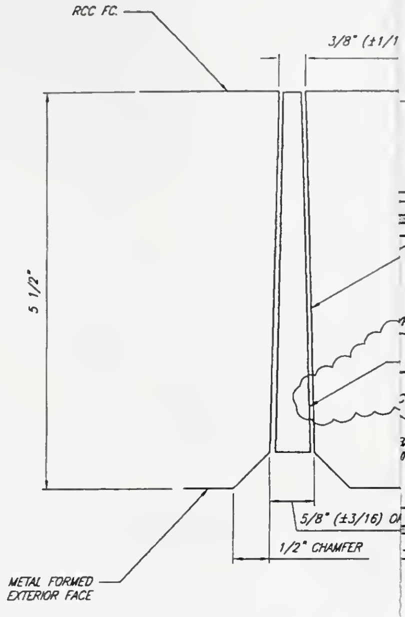
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared by:
ESA Consultants Inc.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

STRUCTURAL
STEPS

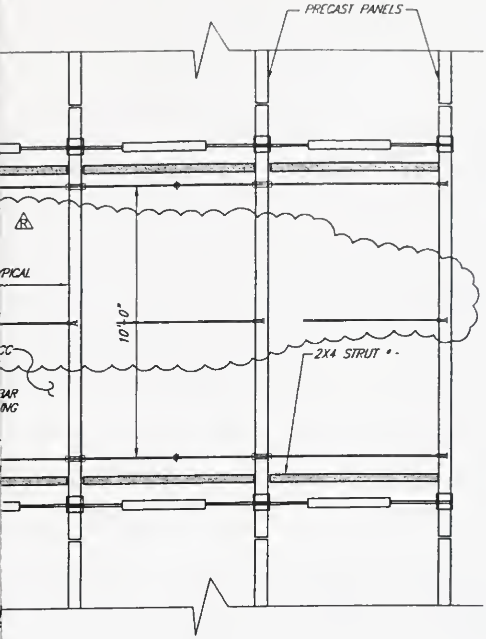
J51

SHEET
S-8

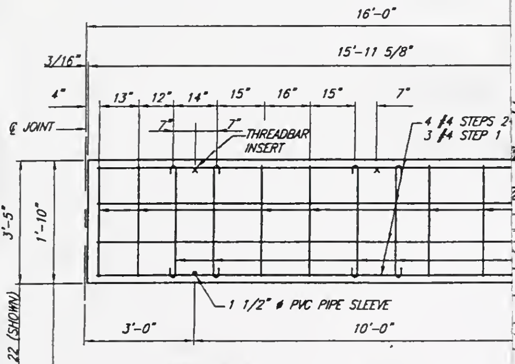


PLAN VIEW
PANEL JOINT DETAI

SCALE: 1"=1"



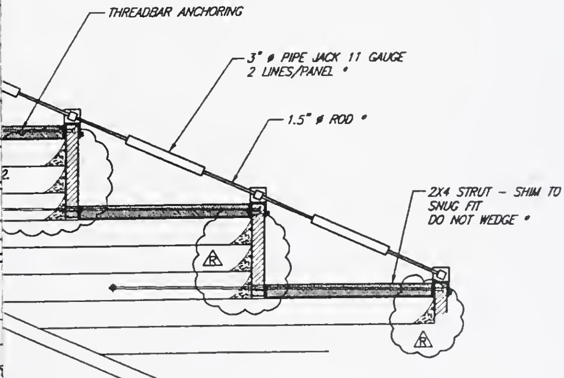
PLAN VIEW



PANEL SCHEDULE					
LOCATION	NO.	DIMENSIONS			C
		thickness	height	length	
STEP 2 THRU 22	882	5 1/2"	3'-5"	16'-0"	
STEP 1	42	5 1/2"	1'-10"	16'-0"	
TRIAL SECTION	6	5 1/2"	3'-5"	16'-0"	

ELEVATION
PRECAST PANEL REBAR

1/2" = 1'-0"



SECTION
MPORARY PANEL BRACING

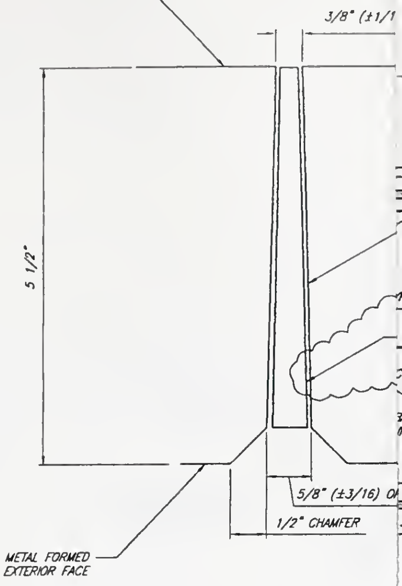
SCALE: 3/8" = 1'-0"

NO	BY	DATE	REVISION DESCRIPTION
R	TBK	9/10/99	RECORD DRAWING REVISION

STRUCTURAL
PRECAST PANELS – DETAILS

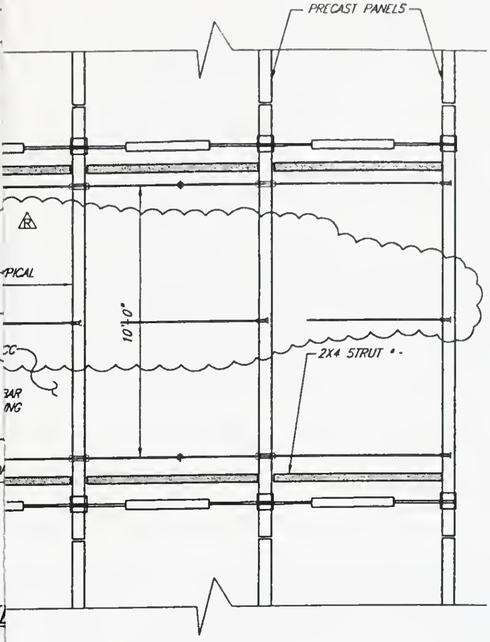
J53

SHEET
S-19

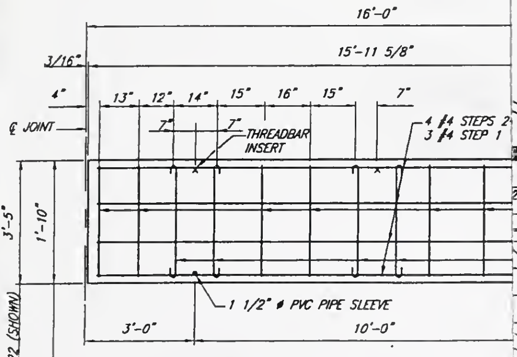


PLAN VIEW
PANEL JOINT DETAI

SCALE: 1"=1"



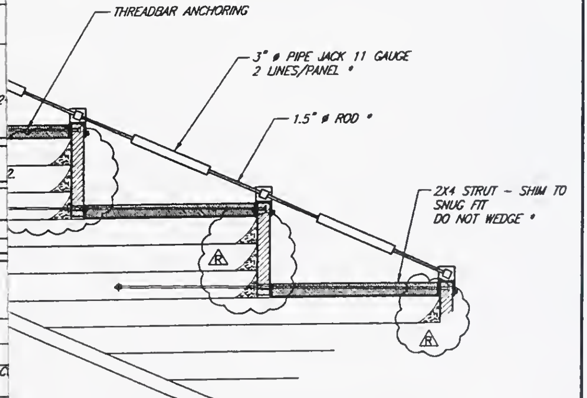
PLAN VIEW



PANEL SCHEDULE					
LOCATION	NO.	DIMENSIONS			C
		thickness	height	length	
STEP 2 THRU 22	882	5 1/2"	3'-5"	16'-0"	
STEP 1	42	5 1/2"	1'-10"	16'-0"	
TRIAL SECTION	6	5 1/2"	3'-5"	16'-0"	

ELEVATION
PRECAST PANEL REBAR

1/2" = 1'-0"



SECTION
MPORARY PANEL BRACING

SCALE: 3/8" = 1'-0"

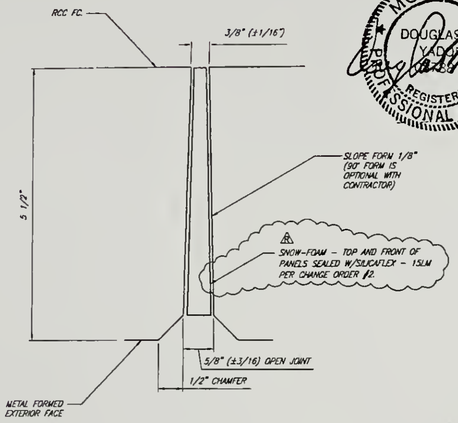
NO	BY	DATE	REVISION DESCRIPTION
R	TBK	9/10/99	RECORD DRAWING REVISION

STRUCTURAL
PRECAST PANELS - DETAILS

J53

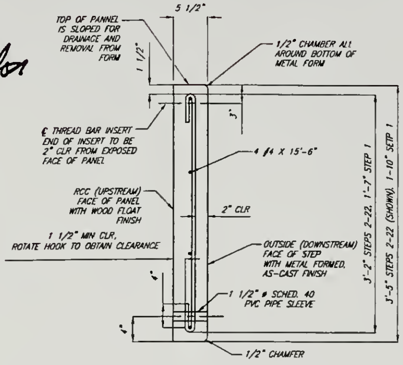
SHEET
S-19

DOUGLAS M. YADON


RCC FC.
3/8" (±1/16")
5 1/2"
SLOPE FORM 1/8" (90° FORM IS OPTIONAL WITH CONTRACTOR)
SNOW-FOAM - TOP AND FRONT OF PANELS SEALED W/SILICAFLEX - 15LM PER CHANGE ORDER #2.
5/8" (±3/16) OPEN JOINT
1/2" CHAMFER
METAL FORMED EXTERIOR FACE

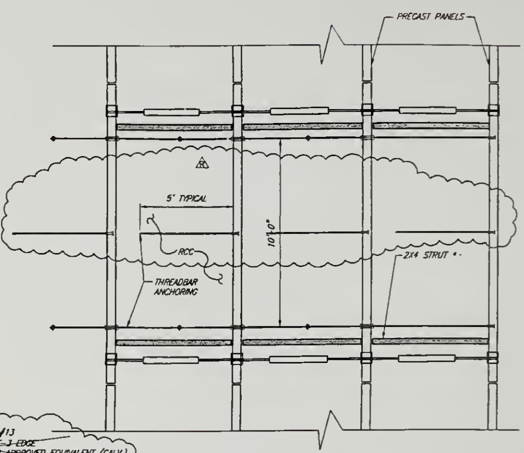
PLAN VIEW PANEL JOINT DETAIL

SCALE: 1"=1"


5 1/2"
TOP OF PANNEL IS SLOPED FOR DRAINAGE AND REMOVAL FROM FORM
1 1/2"
1/2" CHAMBER ALL AROUND BOTTOM OF METAL FORM
℄ THREAD BAR INSERT END OF INSERT TO BE 2" CLR FROM EXPOSED FACE OF PANEL
3"
4 #4 X 15'-6"
RCC (UPSTREAM) FACE OF PANEL WITH WOOD FLOAT FINISH
2" CLR
1 1/2" MIN CLR, ROTATE HOOK TO OBTAIN CLEARANCE
OUTSIDE (DOWNSTREAM) FACE OF STEP WITH METAL FORMED, AS-CAST FINISH
1 1/2" ø SCHED. 40 PVC PIPE SLEEVE
1/2" CHAMFER
3'-2" STEPS 2-22, 1'-7" STEP 1
3'-5" STEPS 2-22 (SHOWN), 1-10" SETP 1

PRECAST PANEL SECTION

SCALE: 1 1/2" = 1'-0"

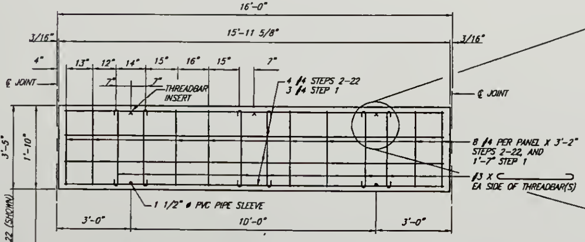


PLAN VIEW

UPON COMPLETION OF THE WORK AND BEFORE FREEZING CONDITIONS PREVAIL, FILL ALL HOLES FROM INSERTS OR OTHER CONTRACTOR EMBEDS AND ANCHORING WITH NON-SHRINK GROUT. THOROUGHLY CLEAN HOLES WITH HIGH PRESSURE WATER AND AIR BEFORE GROUTING.

T-3A PER R.F.I. #13 ~~DAYTON SUPERIOR T-3 EDGE PICK-UP INSERT OR APPROVED~~ EQUIVALENT (GALV.)

THIN SLAB INSERT WITH 4 KIP WORKING LOAD, WITH THREADS TO FIT THE #6 THREADBARS BY "WILLIAMS FORM ENGINEERING CORP." SUBMIT SHOP DRAWING FOR APPROVAL.



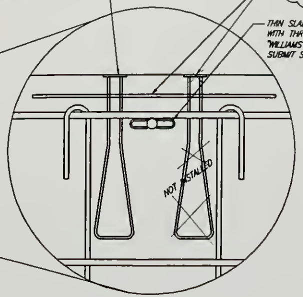
PANEL SCHEDULE					
LOCATION	NO.	DIMENSIONS			COMMENTS
		thickness	height	length	
STEP 2 THRU 22	882	5 1/2"	3'-5"	16'-0"	
STEP 1	42	5 1/2"	1'-10"	16'-0"	
TRIAL SECTION	6	5 1/2"	3'-5"	16'-0"	

3 THREAD BARS ON TOP AND 2 ON THE BOTTOM WERE PLACED IN THE 1'-10" PANELS FOR STEP ONE PER WCD #7.

ELEVATION PRECAST PANEL REBAR

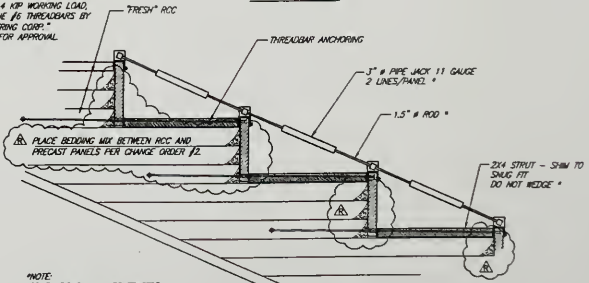
1/2" = 1'-0"

NOTE:
PANELS AT EDGE OF SPILLWAY SHALL HAVE THREADBARS EMBEDDED INTO RCC A MINIMUM OF 3 FEET FROM NEAT LINE. ADJUST THREADBAR LOCATION IN THESE OUTSIDE PANELS OR SHORTEN OUTSIDE PANELS.



DETAIL PANEL INSERT

3" = 1'-0"


"FRESH" RCC
THREADBAR ANCHORING
3" ø PIPE JACK 11 GAUGE 2 LINES/PANEL *
1.5" ø ROD *
PLACE BEDDING MIX BETWEEN RCC AND PRECAST PANELS PER CHANGE ORDER #2.
2X4 STRUT - SHIM TO SNUG FIT DO NOT WEDGE *

*NOTE:
SCHEMATIC ONLY - CONTRACTOR SHOP DRAWING REQUIRED.
SHOP DRAWINGS SHALL INCLUDE BRACING DESIGN CALCULATIONS WHICH INDICATE NUMBER OF BRACED PANEL STEPS PER RCC STEP PLACEMENT. THE MINIMUM NO. OF BRACED PANELS STEPS SHALL BE TWO. SHOP DRAWINGS SHALL INDICATE THE LENGTH OF TIME BETWEEN BRACING MOVEMENTS FOR CURING OF RCC AROUND THREAD BAR ANCHORS.

SECTION

TEMPORARY PANEL BRACING

SCALE: 3/8" = 1'-0"

RECORD DRAWINGS

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ISSUED: SEPTEMBER 1999

NO	BY	DATE	REVISION DESCRIPTION
R	TBK	9/10/99	RECORD DRAWING REVISION

BMC, MAK DRAWN	GFE DESIGNED	PAS CHECKED	SCALE HORIZ. N/A VERT N/A
GFE APPROVED	12/96 DATE	141.9501 PROJECT NO.	

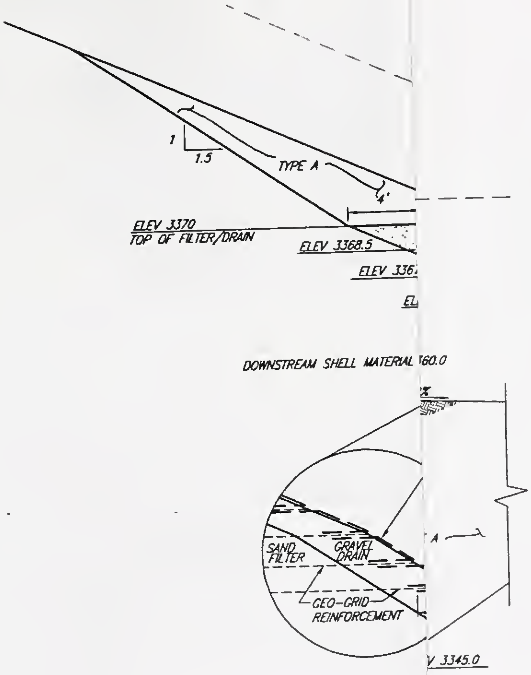
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

STRUCTURAL
PRECAST PANELS - DETAILS

J53

SHEET
S-19



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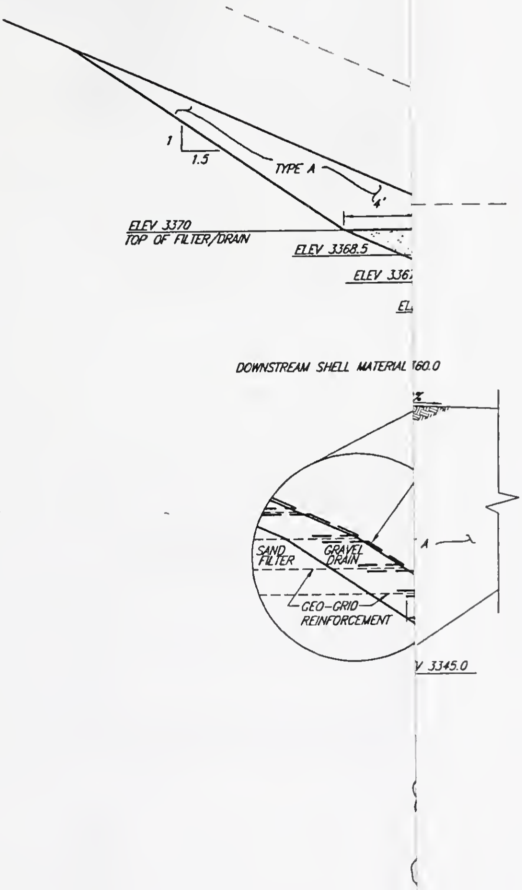
ISSUED: SEPTEMBER 1999

R	TBK	9/13/99	RECORD DRAWING REVISION
1	MAK	2/97	PER ADDENDUM 3
NO.	BY	DATE	REVISION DESCRIPTION

EARTHWORK
TOE DRAIN - SECTION

J55

SHEET
E-16



Douglas M. Taylor

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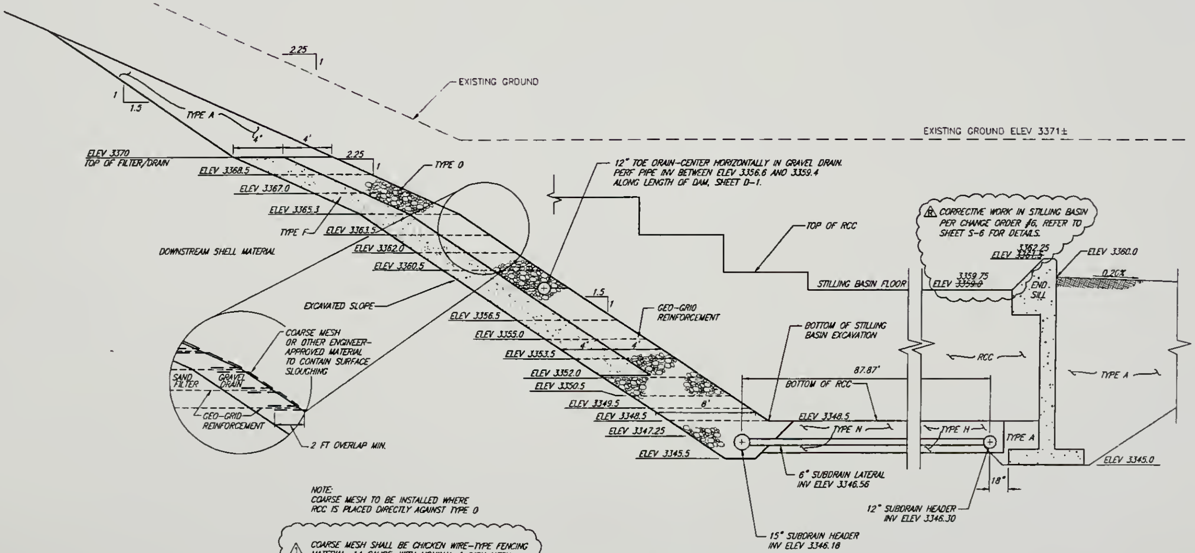
1	MAK	2/97	PER ADDENDUM 3
NO.	BY	DATE	REVISION DESCRIPTION

EARTHWORK
TOE DRAIN - SECTION

J55

SHEET
E-16



NOTE:
COARSE MESH TO BE INSTALLED WHERE RCC IS PLACED DIRECTLY AGAINST TYPE O

△1 COARSE MESH SHALL BE CHICKEN WIRE-TYPE FENCING MATERIAL, 14 GAUGE, WITH NOMINAL 1 INCH MESH.

△R INSTALLATION OF TOE DRAIN SYSTEM SEE FIELD ORDER #10

SECTION A/D-1 FILTER/DRAIN

SCALE: 1" = 4'

RECORD DRAWINGS

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NO.	BY	DATE	REVISION DESCRIPTION
△R	TBK	9/13/99	RECORD DRAWING REVISION
△1	MAK	2/97	PER ADDENDUM 3

MAK DRAWN	DJM DESIGNED	DJM CHECKED
WRK APPROVED	12/96 DATE	141.9501 PROJECT NO.

SCALE
HORIZ. N/A VERT. N/A

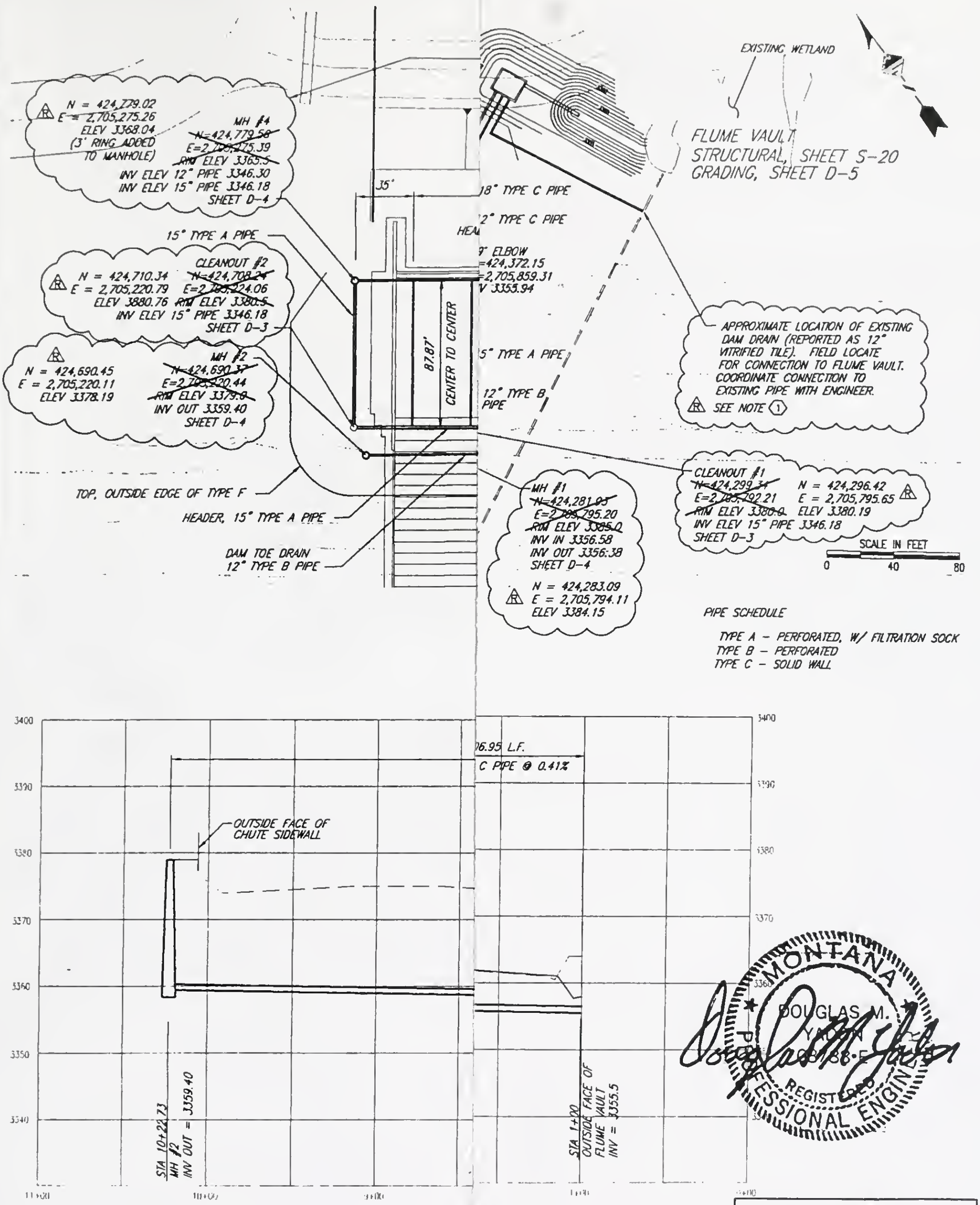
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

EARTHWORK
TOE DRAIN - SECTION

J55

SHEET
E-16



PIPE SCHEDULE

TYPE A - PERFORATED, W/ FILTRATION SOCK
TYPE B - PERFORATED
TYPE C - SOLID WALL

DOUGLAS M.

RECORD DRAWINGS

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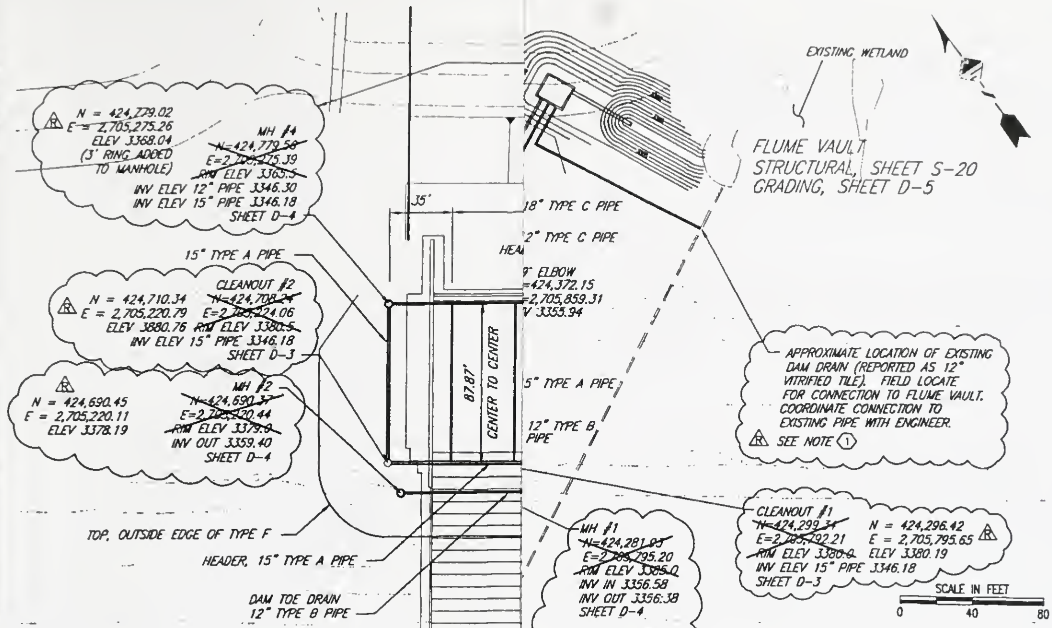
ISSUED: SEPTEMBER 1999

NO	BY	DATE	REVISION DESCRIPTION
△R	SES	10/11/99	RECORD DRAWING REVISION

DRAINAGE SYSTEM
PLAN AND PROFILE

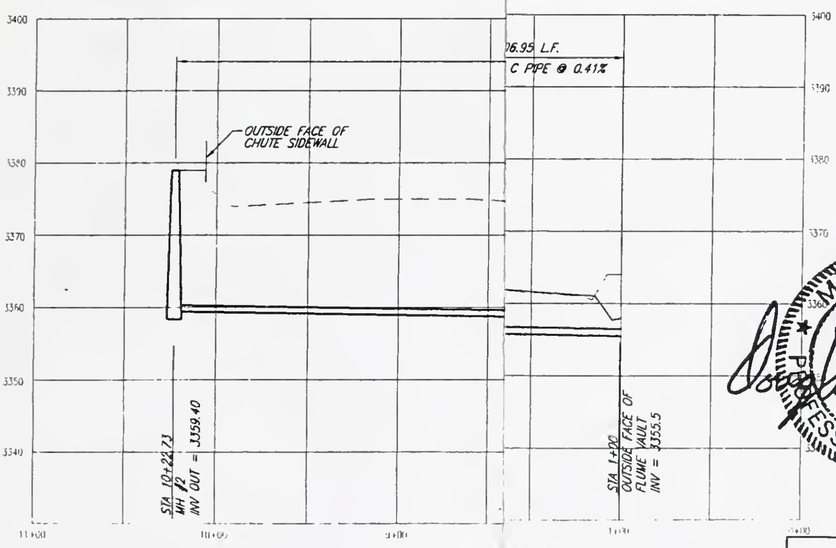
J57

SHEET
D-1



PIPE SCHEDULE

TYPE A – PERFORATED, W/ FILTRATION SOCK
TYPE B – PERFORATED
TYPE C – SOLID WALL



DOUGLAS M.

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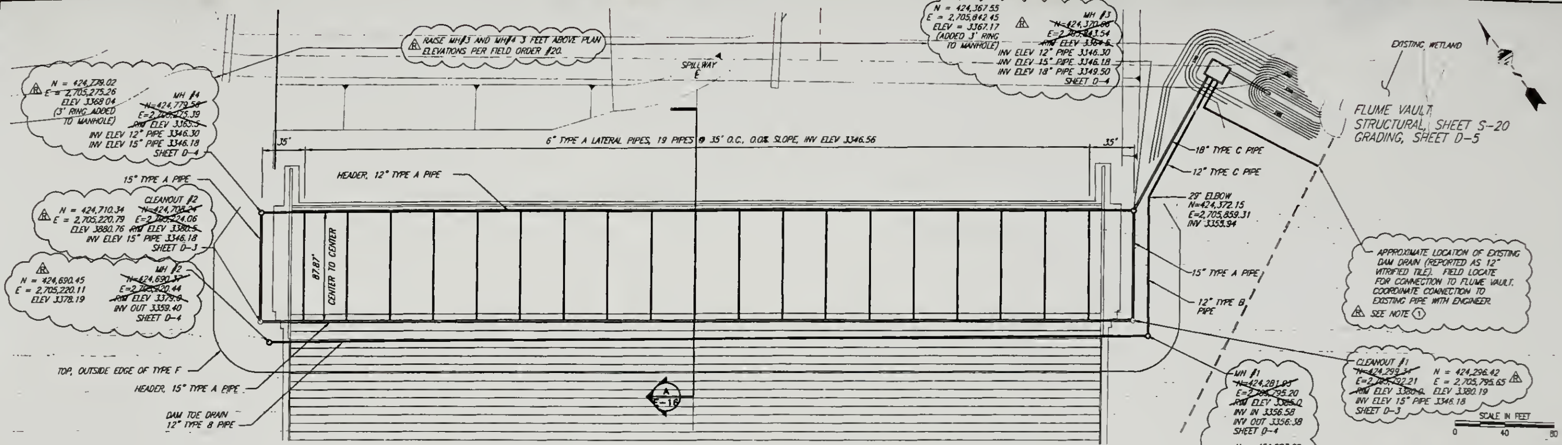
DRAINAGE SYSTEM
PLAN AND PROFILE

J57

SHEET
D-1



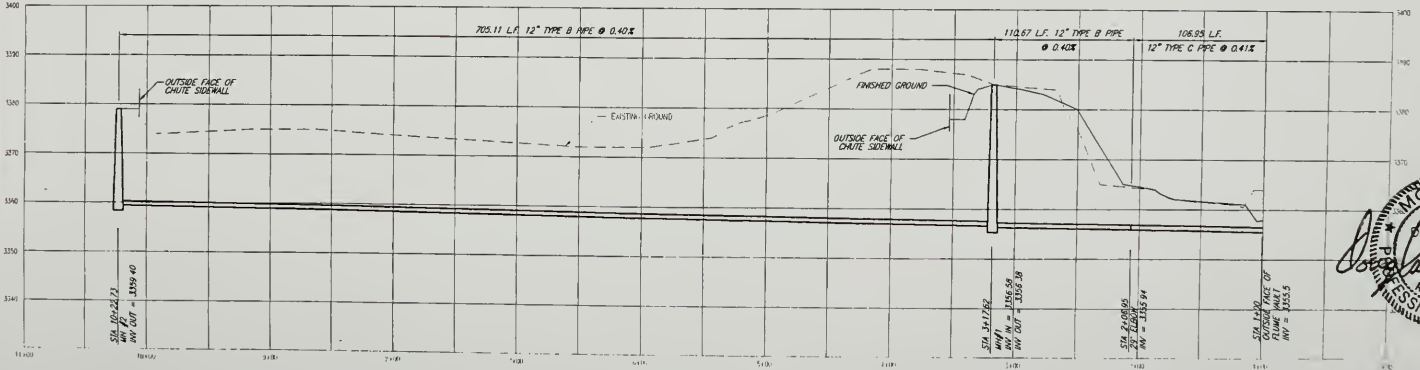
PLAN DRAINAGE SYSTEM

SCALE: 1"=40'

① LOCATED EXISTING DAM DRAIN ON 6/9/97.
INSTALLED FERNCO (RUBBER) COUPLER AT INVERT ELEV. 3349.64. NEW PIPE TO FLUME IS APPROX. 110' LONG WITH A SLOPE OF 0.13%.

PIPE SCHEDULE

TYPE A - PERFORATED, W/ FILTRATION SOCK
TYPE B - PERFORATED
TYPE C - SOLID WALL


3400
3390
3380
3370
3360
3350
3340
705.11 L.F. 12" TYPE B PIPE @ 0.40%
110.67 L.F. 12" TYPE B PIPE @ 0.40%
106.95 L.F. 12" TYPE C PIPE @ 0.41%
OUTSIDE FACE OF CHUTE SIDEWALL
EXISTING GROUND
FINISHED GROUND
OUTSIDE FACE OF CHUTE SIDEWALL
STA 10+22.73 MH #2 INV OUT = 3359.40
STA 3+17.62 MH#1 INV IN = 3356.58 INV OUT = 3356.38
STA 2+06.95 29° ELBOW INV = 3355.94
STA 1+00 OUTSIDE FACE OF FLUME VAULT INV = 3355.5

PROFILE DRAINAGE SYSTEM

SCALE: 1" = 40' HOR
1" = 10' VER

DOUGLAS M. YODER

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R	SES	10/11/99	RECORD DRAWING REVISION

SM DRAWN
DJM/SM DESIGNED
SM/WRK CHECKED
DMY APPROVED
12/96 DATE
141.9501 PROJECT NO.
SCALE HORIZ: 1"=40' VERT. 1"=10'

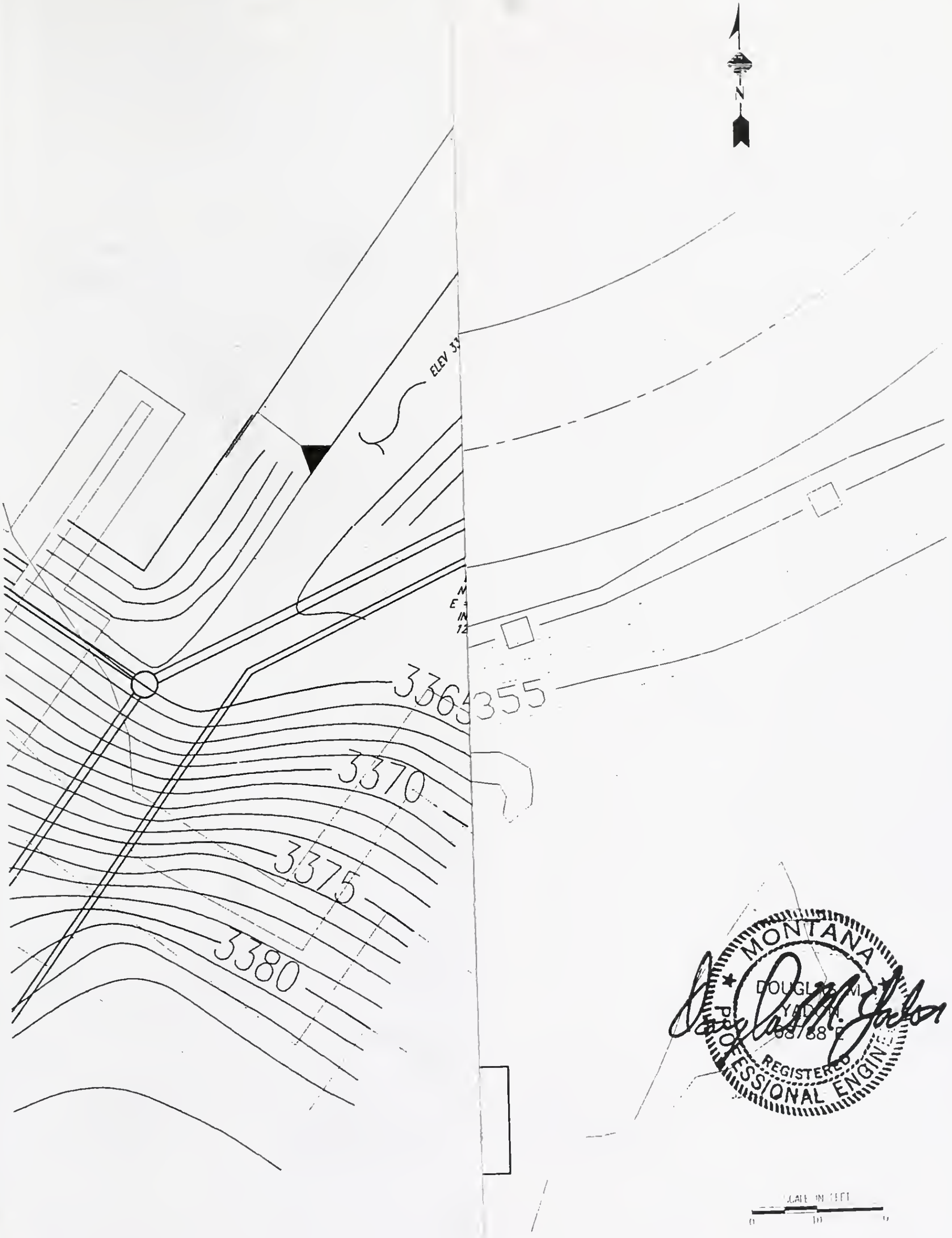
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
310 West Mendenhall, Suite C-1, Bozeman MT. 59715

DRAINAGE SYSTEM
PLAN AND PROFILE

J57

SHEET D-1



MONTANA
DOUGLAS M. YADON
REGISTERED PROFESSIONAL ENGINEER

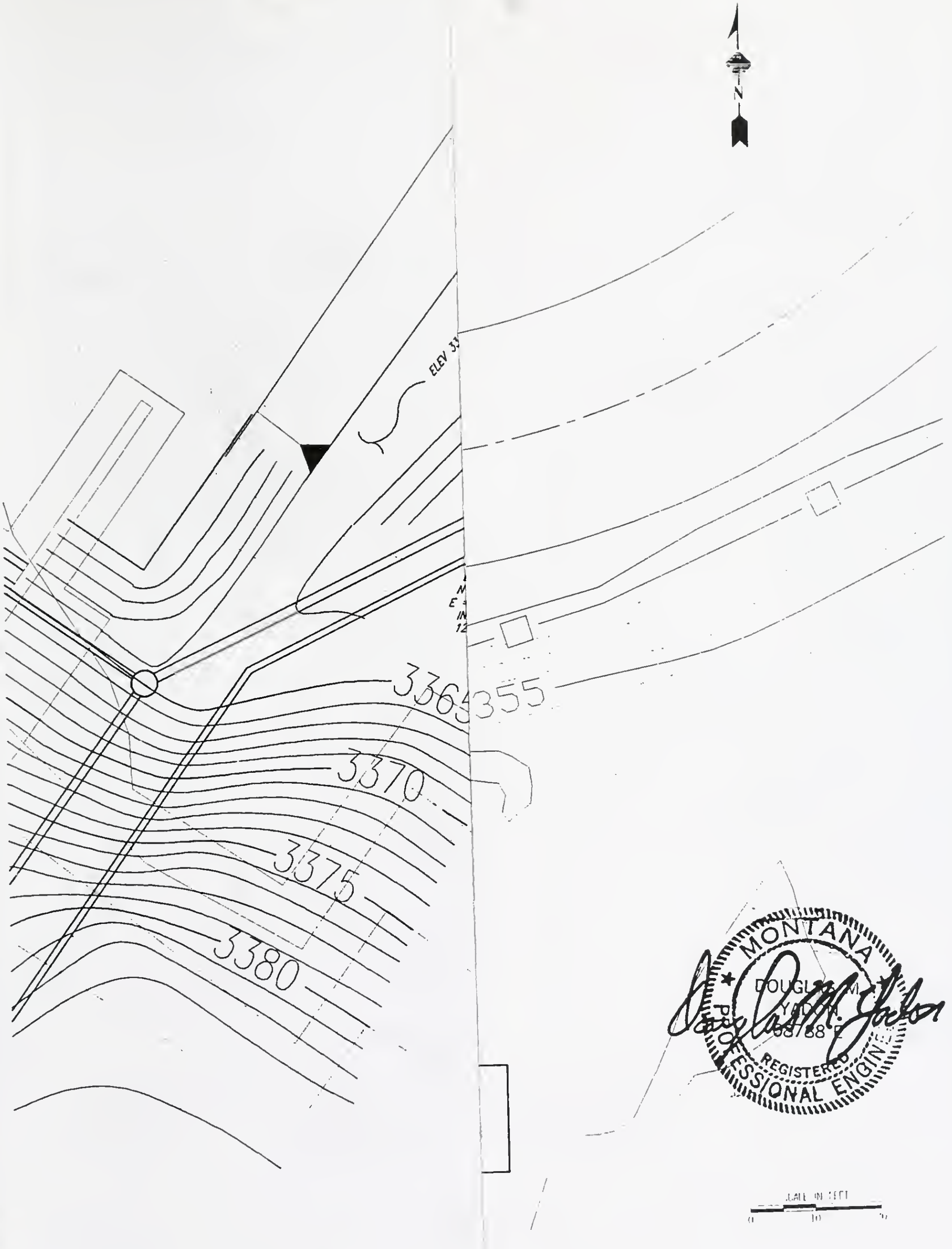
Douglas M. Yadon

R	SES	10/11/99	RECORD DRAWING REVISION
NO	BY	DATE	REVISION DESCRIPTION

DRAINAGE
FLUME VAULT PLAN

J59

SHEET
D-5



Douglas M. Yadon

⚠	SES	10/11/99	RECORD DRAWING REVISION
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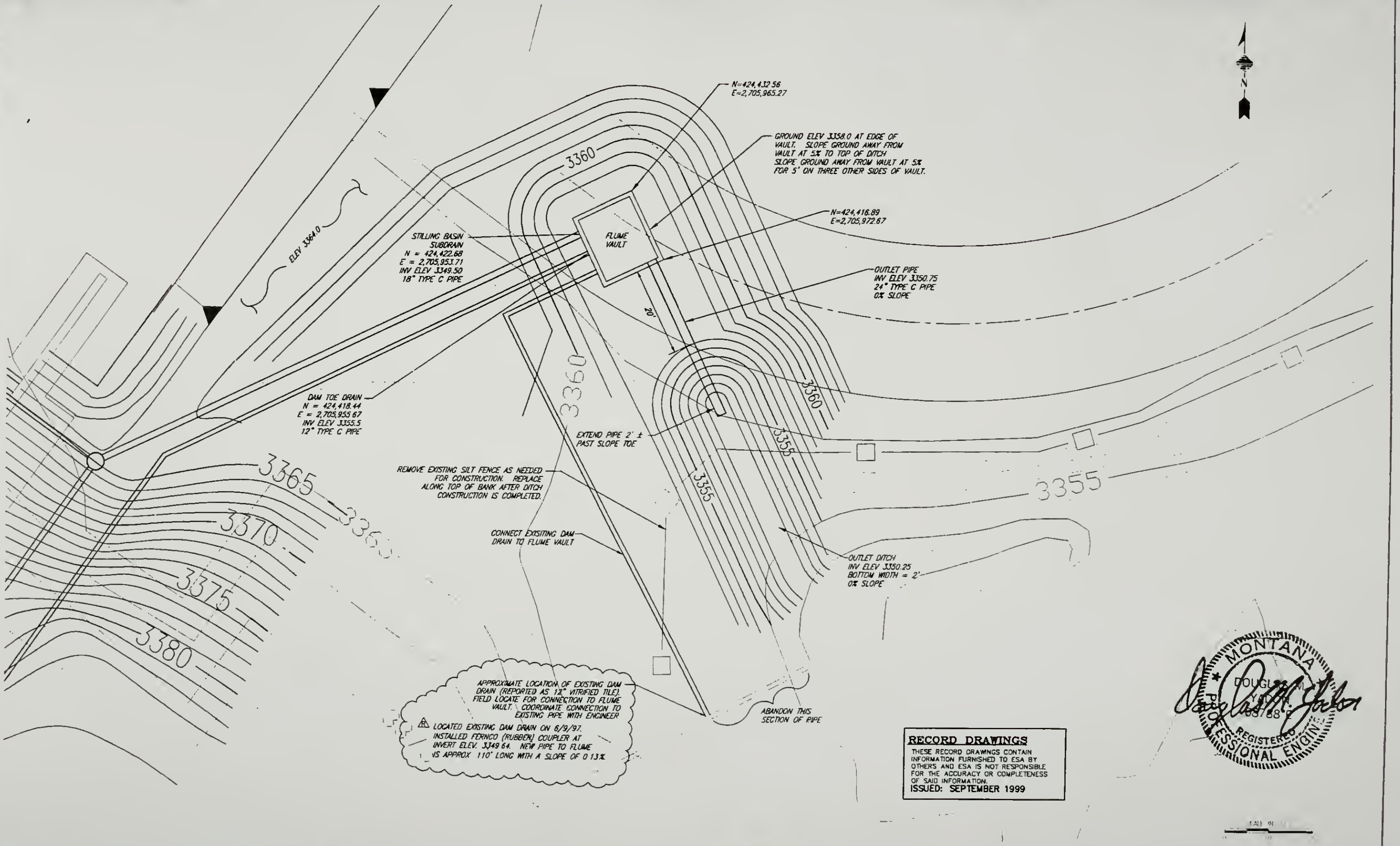
DRAINAGE
FLUME VAULT PLAN

J59

SHEET
D-5


N
N=424,432.56
E=2,705,965.27
GROUND ELEV 3358.0 AT EDGE OF VAULT. SLOPE GROUND AWAY FROM VAULT AT 5% TO TOP OF DITCH SLOPE GROUND AWAY FROM VAULT AT 5% FOR 5' ON THREE OTHER SIDES OF VAULT.
N=424,416.89
E=2,705,972.67
OUTLET PIPE
INV ELEV 3350.75
24" TYPE C PIPE
0% SLOPE
3360
ELEV 3364.0
STILLING BASIN SUBDRAIN
N = 424,422.68
E = 2,705,953.71
INV ELEV 3349.50
18" TYPE C PIPE
FLUME VAULT
20'
DAM TOE DRAIN
N = 424,418.44
E = 2,705,955.67
INV ELEV 3355.5
12" TYPE C PIPE
3360
3360
EXTEND PIPE 2' ± PAST SLOPE TOE
3355
3355
3355
3365
3365
3370
3375
3380
REMOVE EXISTING SILT FENCE AS NEEDED FOR CONSTRUCTION. REPLACE ALONG TOP OF BANK AFTER DITCH CONSTRUCTION IS COMPLETED.
CONNECT EXISITING DAM DRAIN TO FLUME VAULT
OUTLET DITCH
INV ELEV 3350.25
BOTTOM WIDTH = 2'
0% SLOPE
APPROXIMATE LOCATION OF EXISTING DAM DRAIN (REPORTED AS 12" VITRIFIED TILE). FIELD LOCATE FOR CONNECTION TO FLUME VAULT. COORDINATE CONNECTION TO EXISTING PIPE WITH ENGINEER
Ⓡ LOCATED EXISTING DAM DRAIN ON 6/9/97. INSTALLED FERNCO (RUBBER) COUPLER AT INVERT ELEV. 3349.64. NEW PIPE TO FLUME IS APPROX 110' LONG WITH A SLOPE OF 0.13%
ABANDON THIS SECTION OF PIPE

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Ⓡ	SES	10/11/99	RECORD DRAWING REVISION

DRAWN	DESIGNED	CHECKED
SM	SM	SM
APPROVED	**DATE**	**PROJECT NO.**
WRK	12/96	141.9501

SCALE
HORIZ: 1"=10' VERT. N/A

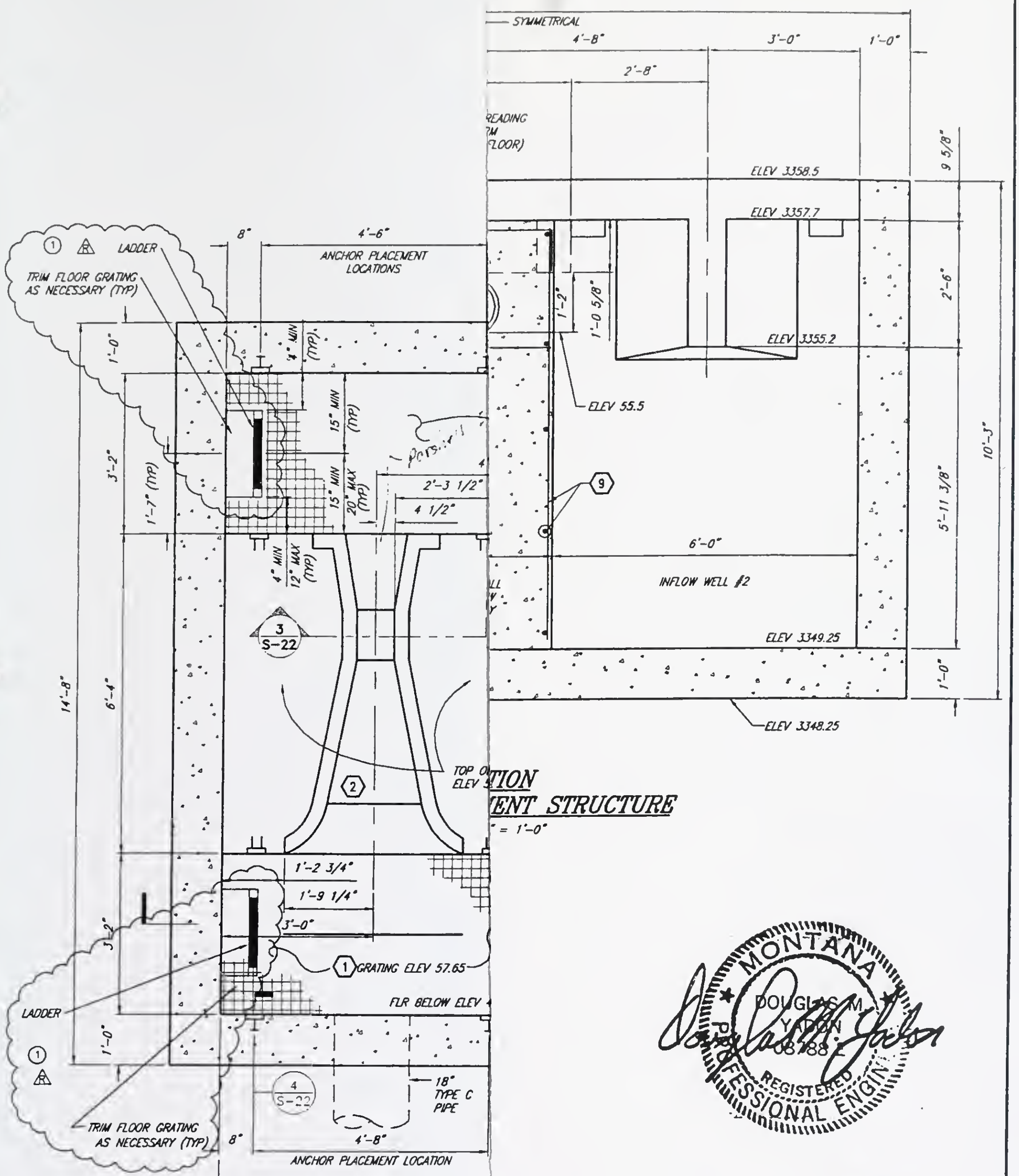
MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
215 West Mendenhall, Suite C-1, Bozeman MT. 59715

DRAINAGE
FLUME VAULT PLAN

J59

SHEET
D-5



FLO

DOUGLAS M. YADON
08788 E

RECORD DRAWINGS
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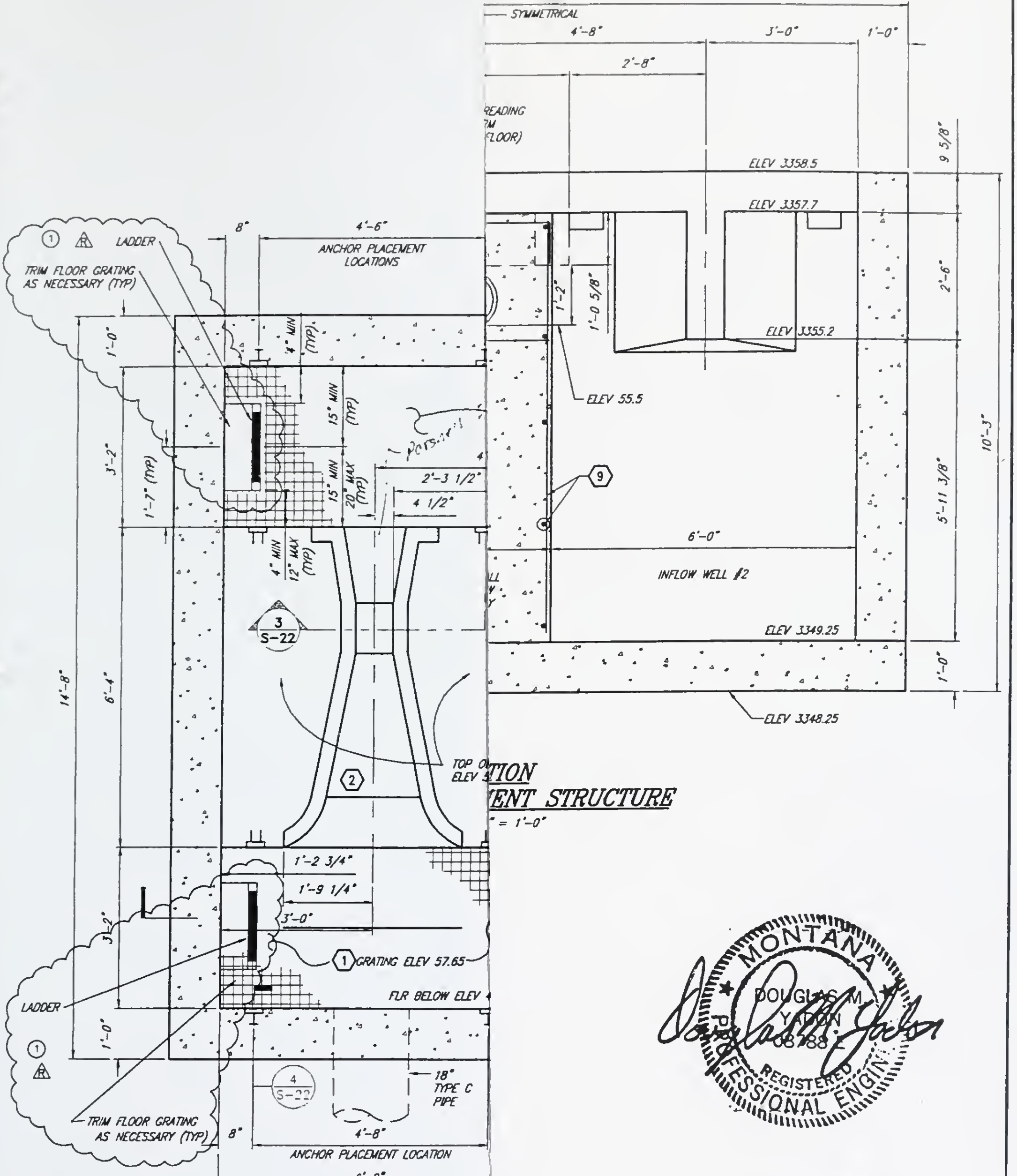
1	SES	10/11/99	RECORD DRAWING REVISION
NO	BY	DATE	REVISION DESCRIPTION

STRUCTURAL
FLUME VAULT

J61

SHEET
S-21



DOUGLAS M. YADON 08788 E

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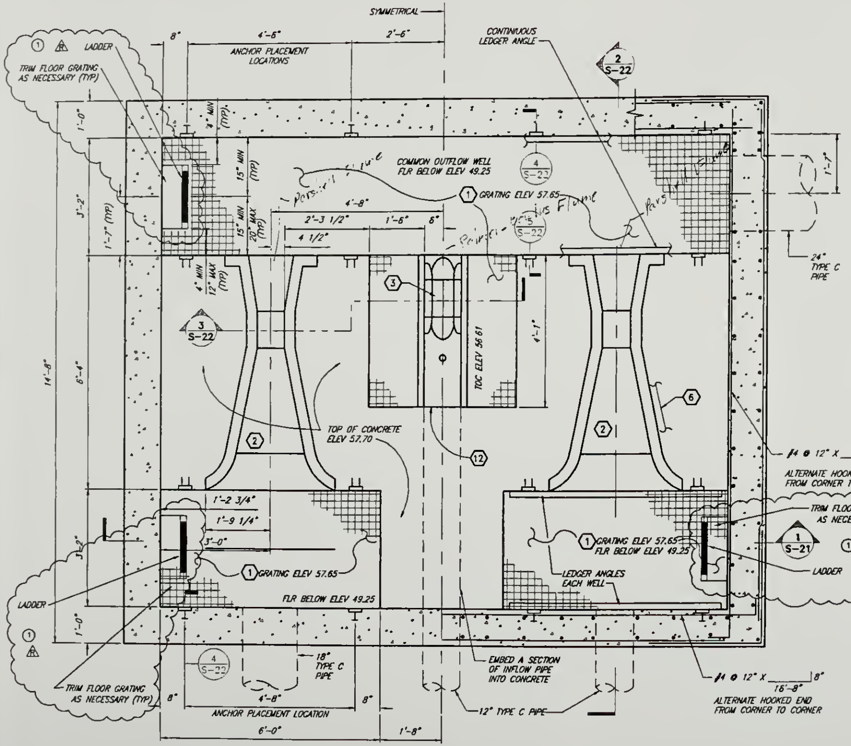
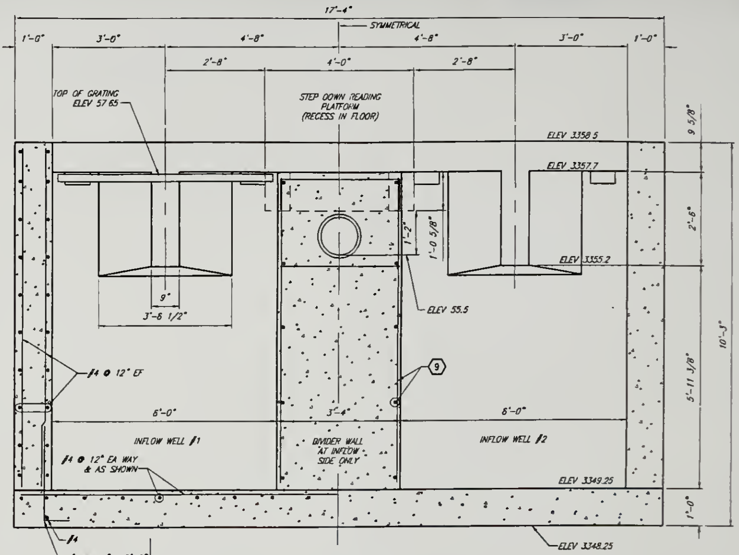
SHEET
S-21



TOP PLAN
FLOW MEASUREMENT STRUCTURE

SCALE: 1/2" = 1'-0"



1 S-21 SECTION
FLOW MEASUREMENT STRUCTURE

SCALE: 3/4" = 1'-0"

NOTES:

① INSTALL FLUME VAULT LADDERS PER WORK CHANGE DIRECTIVE #4.

MONTANA
DOUGLAS M. YADON
6838 E
REGISTERED PROFESSIONAL ENGINEER

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MAK	GFE	PAS	SCALE
DRAWN	DESIGNED	CHECKED	HORIZ. N/A VERT N/A
GFE	12/98	141.9501	
APPROVED	DATE	PROJECT NO	

MONTANA DNRC
TONGUE RIVER BASIN PROJECT
RCC EMERGENCY SPILLWAY

Prepared By:
ESA Consultants Inc.
216 West Mendenhall, Suite C-1, Bozeman MT. 59715

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